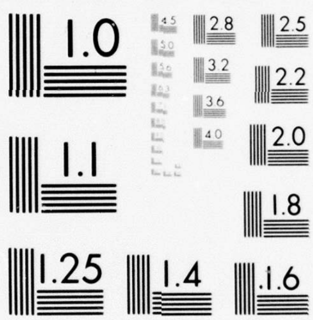
AD-A043 744 RAND CORP SANTA MONICA CALIFORNIA F/G 17/7
GEOMETRIC PERFORMANCE OF PSEUDORANGING NAVIGATION...ETC.(U)
JUL 77 LAMAR, JEANNINE V. ROWELL, L.N. F49620-77-C-0023
UNCLASSIFIED R-1949-AF N/L

1 OF 2
AD A
043744



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF

12
mc

R-1949-AF

July 1977

Geometric Performance of Pseudoranging Navigation Satellite Systems: A Computer Program

Jeannine V. Lamar, L. N. Rowell, J. J. Mate

A Project AIR FORCE report
prepared for the
United States Air Force

Rand
SANTA MONICA, CA. 90406

The research reported here was sponsored by the Directorate of Operational Requirements, Deputy Chief of Staff/Research and Development, Hq. USAF under Contract F49620-77-C-0023. The United States Government is authorized to reproduce and distribute reprints for governmental purposes notwithstanding any copyright notation hereon.

Published by The Rand Corporation

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER R-1949-AF	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Geometric Performance of Pseudoranging Navigation Satellite Systems: A Computer Program		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. V. Lamar, L. N. Rowell, J. J. Mate		8. CONTRACT OR GRANT NUMBER(s) F49620-77-C-0023
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Rand Corporation 1700 Main Street Santa Monica, Ca. 90406		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Project AIR FORCE Office (AF/RDQA) Directorate of Operational Requirements Hq USAF, Washington, D.C. 20330		12. REPORT DATE July 1977
		13. NUMBER OF PAGES 92
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for Public Release; Distribution Unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) No restrictions		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Computer Programs Navigation Satellites NAVSTAR Global Positioning System Position (Location)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) see reverse side		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Describes a computer program designed to analyze many aspects of the geometric performance of pseudoranging navigation satellite (navsat) systems for users either on earth or in earth orbit. A navsat system includes a fleet of satellites, each with an accurate clock that transmits ephemeris, time, and other signals. These signals can be received by relatively small, inexpensive equipment, thus enabling the user to compute his position and time accurately. The NAVSTAR/Global Positioning System (GPS) is such a system, and its overall user accuracy can be broken down into two components which, when multiplied together, yield an estimate of the user's position and/or time accuracy. These two components are analyzed in this report; the first depends on the relative geometry among the navsats being employed and the user's location, and the second involves a determination of system errors. This report was performed as part of a Project AIR FORCE study entitled "Space Warfare Issues," and should be of use to military and civilian defense analysts responsible for the design, use, and survivability of GPS and other U.S. space-related systems. Refs. (HK)

EWP

R-1949-AF

July 1977

100p.

Geometric Performance of Pseudoranging Navigation Satellite Systems: A Computer Program.

Interim rept.,

Jeannine V. Lamar, L. N. Rowell, J. J. Mate

A Project AIR FORCE report
prepared for the
United States Air Force

F49620-77-C-0023

Rand
SANTA MONICA, CA. 90406

1473

296 600

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

LB

PREFACE

This report describes a computer program designed to analyze many aspects of the geometric performance of pseudoranging* navigation satellite (navsat) systems for users either on earth or in earth orbit. A navsat system includes a fleet of satellites, each with an accurate clock, which transmits emphemeris, time, and other signals. These signals can be received by relatively small, inexpensive equipment, thus enabling the user to compute his position and time accurately. The NAVSTAR/Global Positioning System (GPS) currently under development is such a system. The overall user accuracy of such a system can be broken into two components which, when multiplied together, yield an estimate of the user's position and/or time accuracy. The first component, addressed in this report, depends on the relative geometry among the navsats being employed and the user's location. The second involves "system" errors, such as the accuracy of the ephemeris data of the navsats, propagation effects, clock accuracies, etc. Convenient computer analysis of the geometric performance aspect is important in addressing questions of alternative orbital configurations for the navsats and the degradation of performance due to failure or destruction of some or many of them.

The impetus for this research came from Lieutenant Colonel Frank A. Paparozzi, Directorate of Space, Hq USAF (AF/RDSA), who requested an analysis of the utility and feasibility of NAVSTAR/GPS navigation support to high-altitude satellites, for which GPS was not designed.

The research [illegible]formed as a part of a Project AIR FORCE (formerly Project [illegible] study entitled "Space Warfare Issues." It should be of use to military and civilian defense analysts responsible for the design, use, and survivability of GPS and other U.S. space-related systems. Additional Project AIR FORCE research is in progress to analyze GPS Phase III design features needed to support high-altitude space navigation and user equipment, as well as performance, applications, utility, survivability, and alternatives.

---

*Ideally, pseudoranging is a one-way measurement of the true range plus the user's unknown time offset with respect to a master reference.

SUMMARY

This report presents a discussion of pseudoranging navigation satellite (navsat) systems (such as the NAVSTAR/Global Positioning System (GPS) satellite system), of Geometric Dilution of Precision (GDOP), and other geometry-related performance parameters, and a computer program which computes them. Included are satellite selection algorithms which were developed to minimize the computational effort required to obtain the best (or nearly best) set of four required satellites for computing the GDOP for either a satellite-based or earth-based user.

A computer program for earth-based users, developed by the Aerospace Corporation, was acquired and extensively modified. Subject to certain constraints, the original program computed the number of navigation satellites within view of a user at any location, selected the set of four of those within view which would minimize navigation errors, and computed the various values of GDOP--namely, the three-dimensional position error, the horizontal position error, the altitude error, and the time error.

At Rand, the program was modified, extended to accommodate users in any earth orbit, and optimized. Further, facilities were added to give the user convenient and powerful input and output control. In short, the program described here is a flexible "production" program.

In addition to the computation of navigation satellite coverage available to any user and the optimum values of GDOP, the Rand program also includes a feature which permits the variation of the navsat antenna beamwidth and determines the effect of this variation on navigational accuracy for satellite users. There are no restrictions on the shape or size of the orbits of either the navigation satellites or the user satellite.

The computer program is written in FORTRAN IV and has been implemented on an IBM 370/158 computer at Rand. Included in this report are: a program listing, an explanation of the variables, a discussion of the operation of the program, and sample results.

ACKNOWLEDGMENTS

The authors wish to acknowledge the cooperation and assistance of A. Bogen and Paul Jorgenson of the Aerospace Corporation, and of Major Gaylord Green and Captain D. A. Flattery of the Space and Missile Systems Organization (SAMSO/YE). Also appreciated are the reviews of this report and helpful suggestions by Mario Juncosa and Richard Frick of The Rand Corporation.

CONTENTS

I. INTRODUCTION

Pseudoranging navigation satellite systems transmit one-way signals of their ephemeris, time (based on highly accurate and stable onboard clocks that are periodically calibrated by ground command), and other signals that allow a user with fairly simple, lightweight equipment to accurately determine his position, velocity, and time. Such a system, called the NAVSTAR/Global Positioning System (GPS), is being developed by the military services at the Air Force Systems Command Space and Missile Systems Organization. The GPS will eventually consist of 24 satellites with the following configuration:* three orbit planes inclined 63 deg and separated by 120 deg in longitude; eight satellites uniformly distributed in each plane in circular orbits at about 10,900 n mi altitude (12 hr period). (See Fig. 1.) The system is being designed to provide continuous global navigation to terrestrial or near-earth users with accuracies on the order of tens of feet. With modifications, the system could provide high-altitude satellites (above 8000 n mi) with real time navigation support. This navigation support could effect future satellite designs and operations, tracking, telemetry, command and control, and many other space applications.

This report documents a computer program which simulates the orbital motion of a system of pseudoranging navigation satellites (navsats) and the motion of earth-based users or a satellite-based user.** The program computes the number of navigational satellites within view of the user and the Geometric Dilution of Precision (GDOP) values which are dependent primarily on the user/satellite geometry.

The position accuracy provided by such systems can be conveniently divided into two multiplicative factors--GDOP and other "system" errors. The "system" errors depend on the accuracy of the ephemeris data and time transmitted by the navigation satellites, ionospheric and atmospheric effects, and various mechanization, electronic, and processing

---

*The GPS Joint Program Office is considering alternative orbital configurations.

**Ballistic missiles can be treated as satellites with orbital perigees less than earth radius.

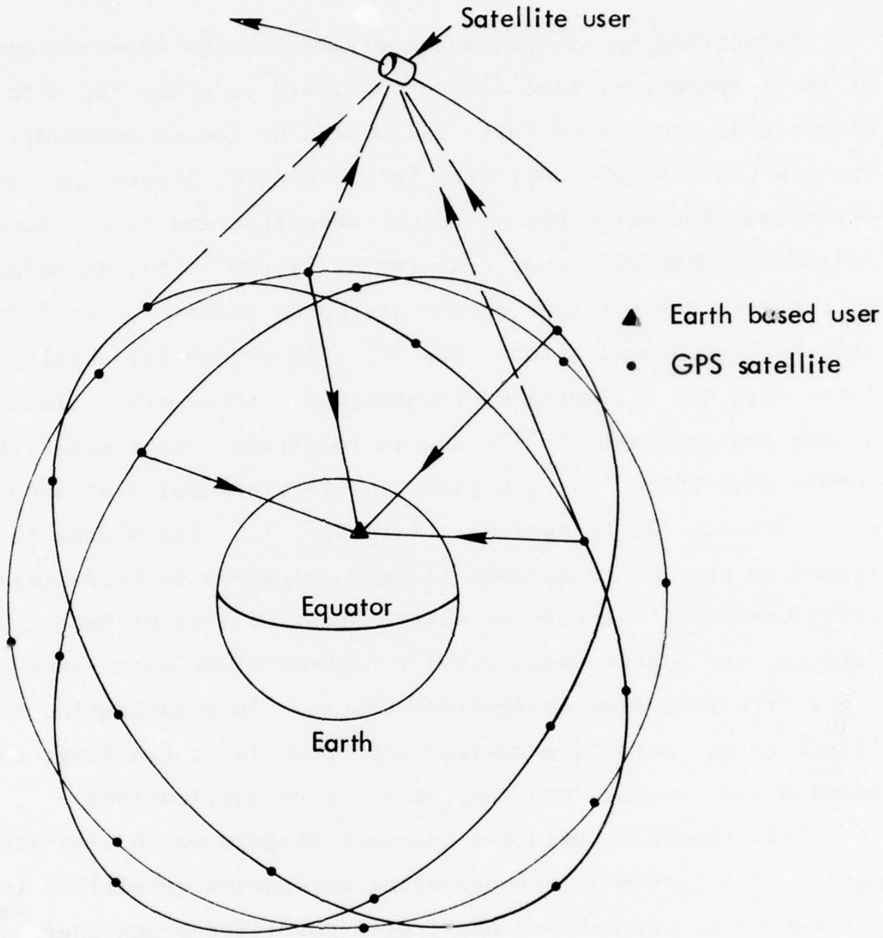


Fig. 1 — Typical configuration of GPS satellites and GPS users

errors in the navigation satellite and user equipments. Since the GDOP factors depend predominantly on the user/navigation satellite geometries, they can be analyzed independently of system errors, which depend on cost, technology, and effort. This allows separate analyses of alternative orbital configurations, user motion, and the loss of some of the navigation satellites by interference or negation.

The original computer program was based on the analyses contained in Ref. 1 and was designed with GPS in mind. Both the referenced report and the original computer program were written by A. Bogen of the Aerospace Corporation. The original program was designed to compute the number of NAVSTAR/GPS satellites available to an earth-based user (or users) and the various GDOP values at specified times. It was written so that the set of navigational satellites can be changed simply by changing the initial orbital elements of each satellite. Satellite motion is assumed to be Keplerian, i.e., all perturbing forces are neglected. Both satellite coverage and GDOP values could be determined for a single earth-based user located at any latitude and longitude or on a global basis, which involved an assumed uniform distribution of earth-based users.

At Rand, the original program has been extensively modified and extended to permit the simulation of a satellite-based user and any orbital configuration of navsats. There are no restrictions on a satellite user's orbit. It can be circular or elliptical and can be entirely above or below the altitude of the navsats, or both above and below (e.g., highly elliptic orbits).

The modifications to the original program to accommodate a satellite user include algorithms which remove unneeded navigation satellites that are in view of the satellite user in order to decrease the amount of computation.*

A user position fix requires a determination of four unknowns: three components of position plus time, thus requiring pseudoranging information from at least four navigation satellites.** Since the GDOP

---

*Some combinations of satellite user orbit and navsat orbit configuration are more expensive to run than others; this will be explained later.

**The inclusion of an explicit time calculation reduces the accuracy and stability requirements for the user's clock, thereby making the user equipment simpler, smaller, lighter, more rugged, and cheaper.

values vary primarily with the relative geometry of the user and the navigation satellites, one objective is to select that combination of four navsats, from all those in view of the user, which will yield the minimum (or near minimum) values of GDOP.

The original computer program contained an algorithm which quickly selected the best combination of four GPS satellites from a maximum number of 11 that an *earth-based* user could see with a masking angle of 5 deg.* (See Fig. 2.) The first of the four satellites is the one nearest the user's zenith and the remaining satellites in view are used three at a time to determine the best combination of four. This is an efficient algorithm that results in the selection of the four navsats which will yield the smallest GDOP *almost* all of the time.** For 11 satellites in view, the maximum that GPS would provide to a terrestrial user, 120 combinations of three are possible after the first satellite has been selected, and there are 330 different combinations of four.

For a satellite-based user, assuming sufficient GPS signal strength in all directions, the masking angle depends only on the user's altitude and the dimensions assumed for the earth and atmosphere. Therefore, as the user's altitude increases, so will the number of satellites in view. For a user above about 8000 n mi altitude, about 21 of the 24 GPS satellites would be in view *if* the satellites were uniformly distributed. In this case, after selecting the first satellite, 1330 different combinations of three satellites are possible, and there are 7315 different combinations of four.

By considering the geometry of the satellite user relative to that of the satellites in view, it is usually possible to eliminate about half

---

*If the 24 GPS satellites were uniformly distributed on the spherical surface 10,900 n mi above the earth, then the expected number in view of a user with a 5 deg masking angle would be eight. However, since GPS satellites are not uniformly distributed, the maximum number in view can be 11.

**Occasionally, there may be a navsat with a slightly larger zenith angle that would result in a different selection of the other three navsats and a smaller GDOP. A switch is provided in the program to bypass the algorithm and consider all combinations of four navsats in view, but is far more expensive to use.

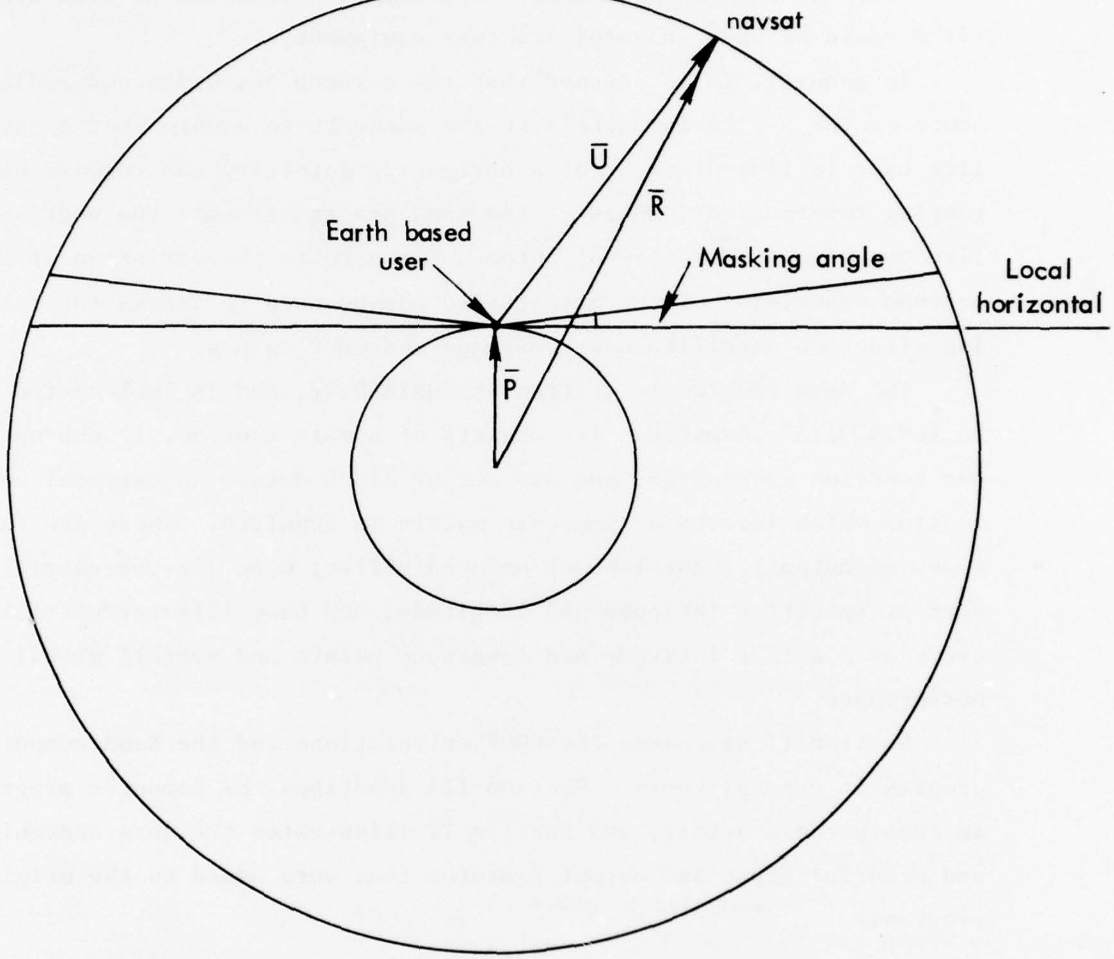


Fig. 2 — User on earth

of them from further consideration. Thus, the original program was not only modified to include a satellite user but also contains an algorithm for such a user that eliminates navigation satellites in view which would not yield small GDOP values. Versions of this algorithm could be used in satellite user equipment.

In general, it is assumed that the antenna beamwidth and radiated power of the navigation satellite are adequate to assure that a satellite user in line-of-sight of a navigation satellite can receive pseudoranging information. However, the Rand program assumes the user satellite has an omni-directional antenna but permits the variation of the antenna beamwidths of the navsats and can be used to assess the resulting effect on satellite user coverage and GDOP values.

The Rand program is written in FORTRAN IV, and is implemented on an IBM 370/158 computer. It consists of a main routine, 12 subroutines, one function subprogram, and one set of block data. An external subroutine which inverts a symmetric matrix is required. There are three types of output: Case I--user on a satellite; Case II--terrestrial user at specified latitude and longitude; and Case III--terrestrial users on a net of latitude and longitude points and overall global performance.

Section II discusses the GDOP calculations and the Rand computer program in general terms. Section III describes the computer program in considerable detail, and Section IV illustrates the more convenient and powerful input and output features that were added to the original program.

II. DISCUSSION

NAVIGATION SATELLITE DEPLOYMENTS

The Rand computer program, which was partly written with GPS Phase III in mind, will accommodate up to a total of 36 navsats in any orbital arrangement. One additional satellite can be a user.

Current plans for the fully operational GPS Phase III call for 24 satellites deployed in 12-hr (about 10,900 n mi altitude) circular orbits inclined 63 deg to the earth's equatorial plane. The 24 satellites will be uniformly distributed in three orbit planes with ascending nodes separated by a longitude of 120 deg. (Alternative orbital configurations are being considered by the GPS Joint Program Office.) The eight satellites in each plane will be separated by 45 deg, and the phasing of the satellites between planes will be chosen to provide optimum navigation geometry. This system will be referred to frequently in the following text and the example solutions shown later are based on this system of navigational satellites.

USER LOCATIONS

Earth-based users can be located at any earth latitude and longitude. The program will compute the GDOP values for a single user, or for multiple users on a global basis. Currently, the program will accommodate only one satellite-borne user. There are no restrictions on the orbital elements of any of the navsats or the satellite user.

NAVIGATION SATELLITE VISIBILITY

In Ref. 1, it is stated that the number of GPS satellites that would be visible to an earth-based user would never be less than 6 nor greater than 11 if the masking angle (elevation angle of the user's line of sight) is 5 deg. Larger masking angles result in fewer satellites being visible to the user and therefore would probably decrease the accuracy in determining the user's position. Although smaller masking angles would, in general, increase the number of satellites visible, atmospheric effects could result in large errors in the pseudoranging

information that the user receives from GPS satellites near the user's horizon due to propagation errors.

For a satellite user, the masking angle required to avoid large atmospheric propagation effects changes rapidly with the user's altitude so that the number of GPS or other navigation satellites in view increases. In fact, a satellite user above about 8000 n mi altitude would, on the average, see 22 of the 24 GPS satellites. At this altitude, only two satellites, on the average, would be obscured from the user's view by the earth plus 200 n mi of atmosphere above the earth. This increase in the number of GPS satellites visible to a satellite user as a function of the user's altitude is shown in Fig. 3.

USER POSITION ACCURACY*

A user of a pseudoranging navsat system needs measurements from four satellites in order to determine his position (three components) and time. The redundancy afforded by having more than four satellites available permits a choice of the one set of four which will yield small values of *GDOP*. These values depend on both the pseudorange measurement errors (system errors) and the relative positions of the four GPS satellites selected.

The geometric relationships between the user's position, the positions of the four navigation satellites, and the four pseudorange measurements are given by Ref. 1:

$$\sum_{j=1}^{3} \left(X_{ij} - U_j\right)^2 = \left(r_i - b\right)^2 , \tag{i}$$

where $i = 1, 2, 3, 4$ and is the index of each of the four equations,

$j = 1, 2, 3$ and is the index for each of three orthogonal directions centered at the user,

X_{ij} = the j^{th} component of the position of the i^{th} navsat,

U_j = the j^{th} component of the position of the user,

r_i = the pseudorange measurement from the user to the i^{th} navsat, and

b = the user's clock bias in units of distance.

---

*These formulations are partly based on information from Paul Jorgenson of the Aerospace Corporation.

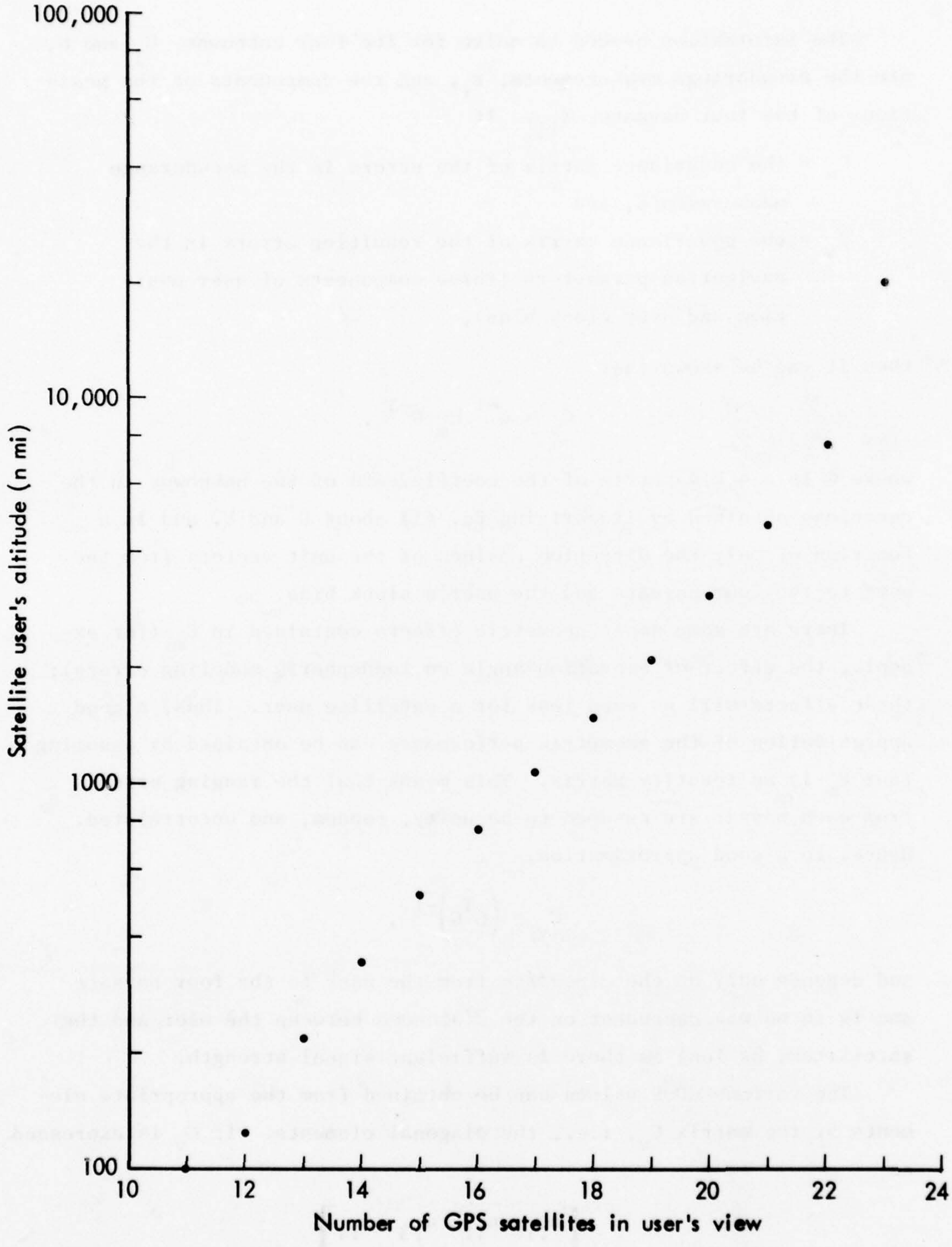


Fig. 3—The average number of GPS satellites visible to satellite users versus user altitude

The information needed to solve for the four unknowns, U_j and b, are the pseudorange measurements, r_i, and the components of the positions of the four navsats, X_{ij}. If

C_m = the covariance matrix of the errors in the pseudorange measurements, and

C_v = the covariance matrix of the resulting errors in the navigation parameters (three components of user position and user clock bias),

then it can be shown that

$$C_v = G^{-1} C_m G^{-T} ,$$

where G is a 4 x 4 matrix of the coefficients of the unknowns in the equations obtained by linearizing Eq. (1) about U and b, and is a function of only the direction cosines of the unit vectors from the user to the four navsats and the user's clock bias.

There are some small geometric effects contained in C_m (for example, the effect of elevation angle on ionospheric modeling errors); these effects will be even less for a satellite user. Thus, a good approximation of the geometric performance can be obtained by assuming that C_m is an identity matrix. This means that the ranging errors from each navsat are assumed to be unity, random, and uncorrelated. Hence, to a good approximation,

$$C_v = \left(G^T G\right)^{-1} ,$$

and depends only on the *direction* from the user to the four navsats and is in no way dependent on the *distances* between the user and the satellites, as long as there is sufficient signal strength.

The various GDOP values can be obtained from the appropriate elements of the matrix C_v, i.e., the diagonal elements. If C_v is expressed as

$$C_v = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} ,$$

an overall measure of geometric effect, GDOP, is obtained from the square root of the trace of the matrix.

$$\mathrm{GDOP} = \left| a_{11} + a_{22} + a_{33} + a_{44} \right|^{1/2} ,$$

where a_{11}, a_{22}, a_{33} relate to errors in position (x, y, z), and a_{44} to the user's time bias.* This factor includes all four unknowns (three dimensions of position and time) and is the conventional measure of overall performance. The other DOP values are:

$$\mathrm{PDOP} = \left| a_{11} + a_{22} + a_{33} \right|^{1/2} ,$$

$$\mathrm{HDOP} = \left| a_{11} + a_{22} \right|^{1/2} ,$$

$$\mathrm{VDOP} = \left| a_{33} \right|^{1/2} ,$$

$$\mathrm{TDOP} = \left| a_{44} \right|^{1/2} ,$$

$$\mathrm{MDOP} = \mathrm{Max} \left| a_{11}{}^{1/2} , a_{22}{}^{1/2} \right| ,$$

where PDOP, HDOP, VDOP, TDOP, and MDOP are the multiplying DOP factors that apply for the three-dimensional position error, the horizontal position error, the altitude error, the time error, and the larger component of the horizontal position error, respectively.

Because the effects of system errors (those independent of geometry) are multiplied by the DOP factors, it is desirable to select the four navsats of those available that will yield minimum DOP values (generally, PDOP).

The results of many computer runs and analytic approximations show that there is almost total correlation between PDOP and the volume of the tetrahedron formed by lines connecting the tips of the four unit vectors from the user toward the four navsats.** Usually (but rarely

---

*The origin of the x, y, z coordinate system (a right-handed system) is at the user's position. The z axis is in the direction of the user's vertical; the x axis points north and the y axis points east in a plane normal to the z direction.

**For example, PDOP can be shown to be inversely proportional to six times the volume of the tetrahedron and directly proportional to the trace of a complicated 3 x 3 matrix.[2]

not), the larger this volume, the smaller the PDOP values. The amount of computational time required to compute this volume is much less than the computation of PDOP itself, which involves a matrix inversion. Thus, the program was designed to first compute the volumes of the tetrahedrons associated with the different combinations of four navsats, identify the combination of four which yields the largest tetrahedron volume, and then use that combination to compute the DOP values. Another advantage of computing the tetrahedron volume as a prelude to computing the DOPs is that the time rate of change of the volume, and consequently an estimate of the time rate of change of PDOP, can easily be obtained;[1] however, this is not implemented in the program.

SATELLITE SELECTION

An earth-based user of a 24-satellite GPS system will see a maximum of 11 of the 24 satellites if his masking angle is as low as 5 deg. If it is assumed that 11 satellites are in view, and the one closest to the user's zenith is chosen as one of the four satellites required, there are 120 combinations if the remaining 10 satellites are taken three at a time. This is not a large number of combinations to be investigated, so the original program did not include an algorithm which would reduce the number of combinations to be examined. There is an option in the present program which allows the satellites to be combined four at a time, without the zenith restriction, but still using the tetrahedron volume.

In the case of a high-altitude satellite user of the baseline GPS configuration, 22 of the 24 satellites may be visible at any time. If this occurs, there are 1330 combinations to be investigated, and there is an option in the program which allows all combinations of four to be examined. An algorithm was developed to eliminate from the calculations those satellites which have unfavorable relative locations. This option usually cuts the execution time for the program by about a factor of 10. In general, about half of the satellites in view can be eliminated. The algorithm is derived in Appendix A.

Figure 4 is a plot of PDOP for a satellite user in a highly elliptic orbit versus time and altitude, and the variation of the parameter

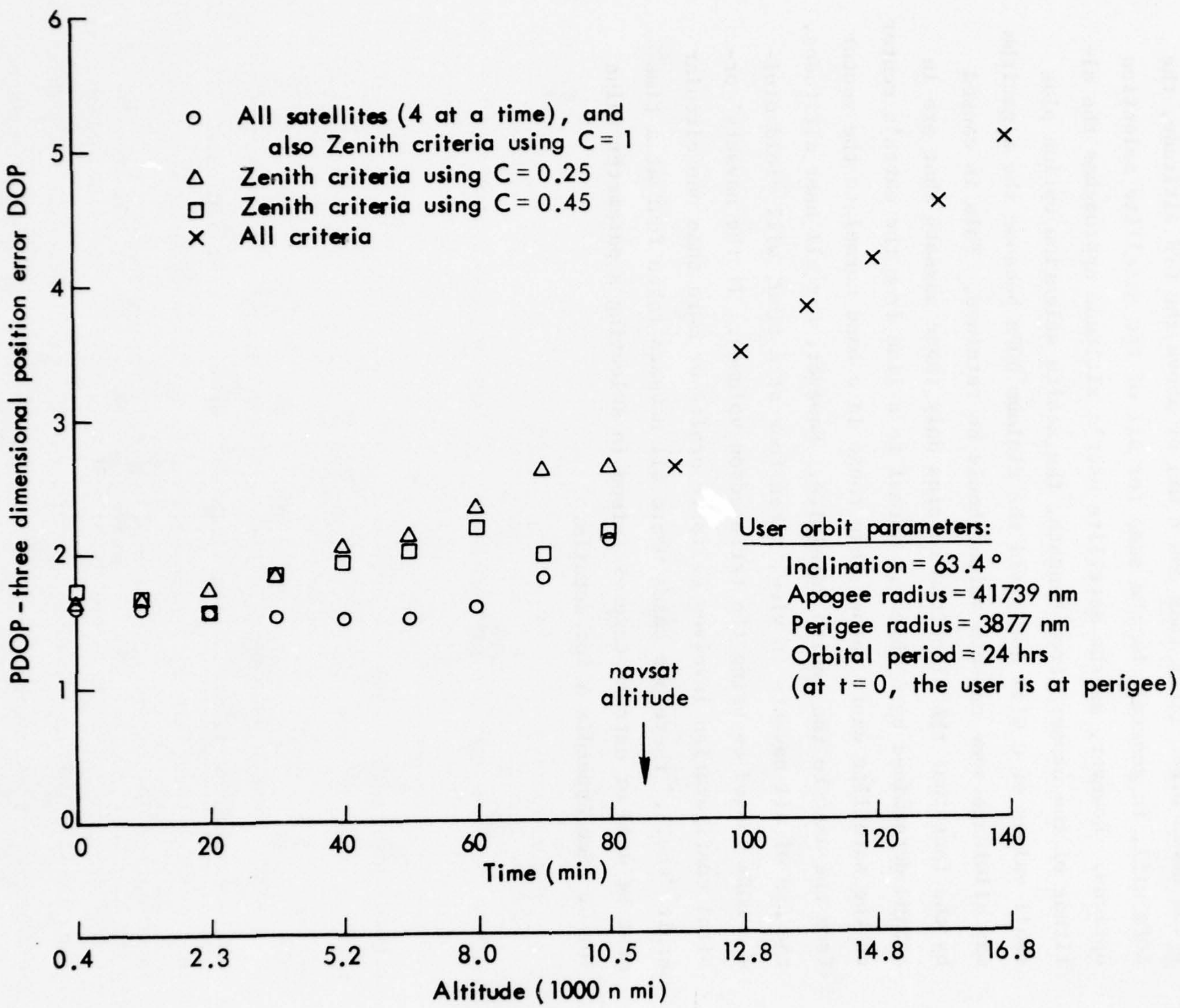


Fig. 4 — Comparison of PDOPs using various satellite selection criteria

value for C, as described in Appendix A. If the user satellite is in a low earth orbit (less than 300 n mi) or above the GPS altitude, the DOPs will, in general, be the same for all of the satellite selection options. However, as the satellite user's altitude approaches the altitude of the navsats from beneath, the zenith selection option plus small values of C will not yield the minimum DOPs because the algorithm may eliminate some navsats which should be retained. This is caused by the fact that the algorithm retains only those navsats that are in a band determined by C which is normal to a line from the earth's center to the satellite user, rather than those in a band normal to the vector from the user to the zenith satellite. However, for all user altitudes, the use of all navsats in view, taken four at a time, will yield minimum DOPs (based on using the tetrahedron volume). If the navsats' orbital configuration involves elliptic orbits or more than one circular orbit "shell," there are cases where all navsats taken four at a time must be used or extreme care exercised in selecting a parameter value for C. See Appendix A for details.

III. COMPUTER PROGRAM OPERATION

The first card of the input contains the switch for choosing the case desired (LOC: LOC = 1, satellite user; LOC = 2, earth-based user: LOC = 3, global calculations); the number of navsats (NJL); and the switch for choosing the navsat selection technique (ISCMP: ISCMP = 0, zenith; ISCMP = 1, all satellites, four at a time).

There are three types of calculations performed by the program: in Case I, the user is on a satellite; in Case II, the user is stationed at a specific latitude and longitude on the earth's surface; and, in Case III, a group of users are located at a set of latitudes and longitudes which form a net over the whole surface or a hemisphere of the earth.

Along with each of the three cases, there is a choice of the navsat selection technique to be used. In Case I, when the user is on a satellite, one choice is to use the navsat which is most nearly above *or* below the user as one of the four satellites in the calculation of the volume of the tetrahedron (zenith or nadir mode); the other choice is to use all of the navsats in view, taken four at a time. In Cases II and III, one choice is to use the navsat most nearly overhead of the earth-based user as one of the four satellites in all calculations of the volume, and the other choice is all of the satellites in view taken four at a time.

In all cases, the basic input to the program is the number of navsats and their orbital elements: eccentricity, argument of perigee, right ascension, inclination, initial true anomaly (at t = 0), and period. On the input cards, NJL is the number of satellites in the navsat system. P(N,K) is the array into which the orbital elements are read, where N is the identification number of the navsat, and K = 1 to 5 is the index on the first five orbital elements. The index K is held constant and the orbital element for that index is read in for all navsats (i.e., all eccentricities, then all arguments of perigee, etc.). The final inputs for the navsats are their periods, which are read into the array PER(N). After these inputs, navsat user related data is read in, which varies by case.

For Case I, NJL + 1 is the number of the *user* satellite. The first satellite user data card of a Case I input contains the eccentricity, argument of perigee, right ascension, inclination, and initial true anomaly of the user satellite at t = 0. The second card contains the period of the user, the antenna beamwidth half-angle of the navsats relative to a vector from the navsat to the center of the earth (AIN), and a numerical value (C) used in the calculation of the width of the band on the spherical surface containing the navsats, where the satellites for consideration in the "DOP" calculations will be sought (see Appendix A). The third card contains the time increment, in minutes, at which the calculations are desired (INC), and the total number of these time increments, plus one (ITF).* For each run, the first page of output contains the orbital elements and all other input values. The subsequent output for Case I is the user altitude, VDOP, HDOP, MDOP, TDOP, PDOP, and GDOP at the chosen time increments, plus the identification numbers of the four navsats used *and* all others in view. If there are less than four satellites in view, there will be no print line for that time step--it is merely skipped and the program continues.

The first navsat user data card for a Case II run contains the latitude (ATL), longitude (ONGL), and masking angle of the user (ELEVAT, see Fig. 2). The second card contains the time increment, in minutes, at which the calculations are desired (INC) and the total number of these time increments required, plus one (ITF).* The output for Case II is identical to Case I--except that the altitude is always zero.

In Case III, the users are located at a set of latitudes and longitudes which form a net over the surface of the earth. The prime objective of this Case is average overall system performance for earth users over a period of time, with a secondary objective of providing a "snapshot" of the DOPs at specified time steps at each longitude and latitude intersection specified. For overall performance, global statistics are calculated for a uniform distribution** of users over the surface of the earth or in the northern hemisphere, and for a full

---

*The "plus one" accounts for the "zero" time point.

**A uniform distribution of users is approximated by the DOPs of users at a given latitude by the cosine of that latitude.

orbital period or a symmetrical part thereof. The total time input must assure this condition if overall performance for earth users is the objective.

The net of users can be chosen in various combinations. Basically, the calculations can be done at 10 deg steps in both longitude and latitude, covering the whole surface or the earth; or at 10 deg steps of longitude and 5 deg steps of latitude for covering the northern hemisphere. In addition, increments of these basic steps can be chosen so that the calculations will be performed at every 20 or every 30 deg, etc., of longitude and at every 20 or every 30 deg., etc., or at every 5 or every 15 deg, etc., of latitude. Global statistics calculations averaged over time are output at the completion of the calculations, but a "snapshot" of the DOPs at each longitude and latitude selected are available at any time point.

The first navsat user card for a Case III input contains the latitude step size (LATDEG) and the masking angle of the users (ELEVAT). The second card contains the latitude increment (LATIC) and the longitude increment (LONIC). If LATIC = 3 and LATDEG = 5, then calculations will be made at 0, 15, 30 deg, etc., in latitude. If LONIC = 2, then calculations will be made at 0, 20, 40, deg., etc., in longitude. The second card also contains the time increment, in minutes, at which the calculations are desired (INC) and the total number of these time increments, plus one, required to complete a full orbital period or to reach a condition of symmetry (ITF), if overall performance is the objective. The final two variables on the second navsat user card are concerned with the "snapshot" request. If IPFREQ = 0, no "snapshot" calculations are made; if it is greater than 0, then ITIME is set to an interger and "snapshot" calculations will be made and printed. For example, if the user has chosen INC = 10 and ITIME = 5, then "snapshot" output will occur at time = 0, 50, 100, etc. If the "snapshot" calculations are requested, the user will always get output at time = 0.

Since the program is quite costly for global calculations, the computation time step should be small enough to insure a representative global distribution. The size of the time step will depend on the navsat orbital configuration. Output for the average overall global

performance are elevation distribution, latitude elevation distribution, accumulative global distribution of DOPs, maximum and minimum number of satellites seen at the latitudes and longitudes of the net, the probability of seeing exactly N satellites, and the probability of seeing N or more satellites both by latitude and on an average (weighted by the cosine of latitude) global basis.

Table 1 (pages 19-22) contains an explanation of the variables in the MAIN program, and Table 2 (pages 23-27) contains an explanation of the variables in the subroutines and in their calling sequences. Table 3 (pages 28-29) shows the manner in which the input cards are set up. Appendix B provides a listing of the entire program.

A few timed runs were made. Table 4 (page 30) shows a comparison of some of the computing parameters.

The program has been dimensioned to accommodate a total of 36 navsats. In Case I, this means 36 navsats and one satellite user. Cases II and III are limited to a maximum of 36 navsats. All cases can evoke the option of using all navsats in view, taken four at a time, but, in Case III and in Case I (for high-altitude satellite users), the run time would be prohibitive. If less than 36 satellites are to be used, the dimensions of matrix KXX(I,4) (in MAIN, and in subroutines TAAT and TALL) should be reduced to cut down core storage. The index I is calculated from the formula

$$I = \frac{n!}{r!\,(n - r)!}\ ,$$

where n = number of navsats and r = 4.

For Case I, the calculations become less accurate as the altitude of a user above the navsats increases. The subroutine which inverts the DOP matrix is in double precision in order to alleviate some of this problem. However, above a ratio of satellite user altitude to navsat altitude of about 20, the matrix becomes sufficiently ill-conditioned that errors begin to occur in the DOPs.

Table 1

EXPLANATION OF VARIABLES IN MAIN PROGRAM

A. USER ON SATELLITE

FORTRAN	Equations	Explanation
RF(IV), RMX(N,IV), R(IV)	$\overline{R}$ [a]	Vector from the center of the earth to a navsat (where N is the "identification number" of the navsat and "IV" is the index of the components of the vector)
UPV(IV), RMX(IP,IV)	$\overline{P}$	Vector from the center of the earth to a user satellite (where "IP" is the "identification number" of the user satellite and "IV" is as above)
UTS	$\overline{U}$	Vector from a user satellite to a navsat
AR	R	Length of vector $\overline{R}$
AP	P	Length of vector $\overline{P}$
A		$\cos^{-1}(r/R)$, r = earth radius
B		$\cos^{-1}(r/P)$
PHI	ϕ	$\cos^{-1}(r/R) + \cos^{-1}(r/P)$
THETN	θ_n	$\cos^{-1}(\overline{R} \cdot \overline{P}/RP)$
AU	U	Length of the vector $\overline{U}$
BETAN	β_n	$\cos^{-1}(-\overline{U} \cdot \overline{P}/UP)$
AIWID	α	Navsat antenna beamwidth half-angle (input) relative to a vector from the navsat to the center of the earth
BWIDTH		$\pi - (\theta_n + \beta_n)$

[a] An overscore denotes a vector.

Table 1 (continued)

FORTRAN	Equations	Explanation
USUV(IINT(N),IV) U(IV)	$\bar{e}_1$, $\bar{e}_2$, $\bar{e}_3$, $\bar{e}_4$	Unit vectors from a user toward 4 navsats (where IINT(N) contains the "identification number" of the satellites which have not been eliminated and "IV" as above)
THETT	θ_T	If $P > R$ $\theta_T = \cos^{-1} (R/P)$
		If $P \leq R$ and β (of the navsat closest to zenith or nadir) $> \pi/2$; $\theta_T = 109.5° - \sin^{-1} (P \sin 19.5°/R)$[b]
		If $P \leq R$ and β (of the navsat closest to zenith or nadir) $\leq \pi/2$; $\theta_T = 70.5 - \sin^{-1} (P \sin 19.5°/R)$[b]
DELONE	δ_1	If $\sin^2 \theta_T > C$ $\delta_1 = \sin^{-1} (C/\sin \theta_T)$
		If $\sin^2 \theta_T \leq C$ $\delta_1 = \theta_T$
DELTWO	δ_2	If $\sin^2 \theta_T > C$ $\delta_2 = \delta_1$
		If $\sin^2 \theta_T \leq C$ $\delta_2 = \cos^{-1} (1 - 2C) - \theta_T$

[b]See Appendix A.

Note

After the calculations for eliminating satellites which are not to be considered in the set for navigational purposes, the ones to be used are located as follows:

IOS(I) As I is incremented from 2 to the number of satellites to be included in the navigational calculations, the "identification numbers" of those satellites are stored in IOS.

IOS(1) always contains the "identification number" of the satellite which is closest to zenith or nadir.

Table 1 (continued)

B. USER ON GROUND[c]

FORTRAN	Explanation
R,RMX	Vector from the center of the earth to a navsat
UPV	Vector from the center of the earth to a user
STN	Vector from a navsat to a user
SE	Elevation (masking) angle of a satellite
UTS	Vector from a user to a navsat (-STN)
USUV	Unit vector (of UTS)
NSTO	Total number of navsats in view
NSPL(L)	Total number of navsats in view at each latitude
CL(L)	Total number of latitudes when there are four or more navsats in view
Z	Vector in the polar direction $\overline{Z}$ (origin at the earth's center)
YE	Vector in the eastward direction (origin at the user)
XN	Vector in the northward direction (origin at the user)
G(NSGD(N),I)	Direction cosines (where NSGD(N) contains the "identification numbers" of the four selected navsats and I = 1,4)
SIGT	Dimensioned at 6, contains the dilution of precision (DOP) parameters
CDOP(L,K,IDOP)	Storage for DOPs for each time step; L = latitude index, K = longitude index, IDOP = DOPs index
PIB(IX)	Elevation distribution--the probability that the satellite in view will have specified elevation angles; IX = elevation angle index

[c]This portion of the program is explained in Ref. 1.

Table 1 (continued)

FORTRAN	Explanation
CAGX(LA,LC)	Latitude elevation distribution--the probability that any navsat in view will have an elevation angle greater than or equal to those specified; LA = latitude index, LC = elevation range index
GLEB(IC)	Accumulative elevation distribution--the probability that the elevation angle to a navsat is greater than or equal to those listed; IC = elevation range index
QSR(IQSR)	Range into which the printed variable falls; IQSR = 1, 36 in steps of .2
SKEGX(LK,IQSR,JDOP)	Dilution of precision parameters for overall global performance; LK = latitude index, IQSR (see above), JDOP = DOPs index
MAX(IL,IK)	Maximum number of navsats seen at the intersections of latitudes and longitudes; IL = latitude index, IK = longitude index
MIN(IL,IK)	Minimum number of navsats seen at the intersections of latitudes and longitudes; IL = latitude index, IK = longitude index
OBLAT(IL,N)	Probability (in percent) of seeing exactly N navsats; IL = latitude index, N = number of navsats
ACLAT(IL,N)	Probability (in percent) of seeing N or more navsats; IL = latitude index, N = number of navsats
OBDIS(N)	On a global basis, the probability (in percent) that exactly N navsats will be seen (as above)
ACTOT(N)	On a global basis, the probability (in percent) that N or more navsats will be seen (as above)

Table 2

EXPLANATION OF VARIABLES AND CALLING SEQUENCES OF SUBROUTINES

The subroutine call with the variable names in its argument list, as it appears in MAIN, is shown first. The subroutine name, with the variable names in its argument list and an accompanying explanation, appears second.

ORBINI(N)

ORBINI(I)	I, satellite number	
P(I,2)=P(I,2)*C(1)	Argument of periapsis x 0.01745	Calculated only to change units from degrees to radians
P(I,3)=P(I,3)*C(1)	Right ascension of the node x 0.01745	
P(I,4)=P(I,4)*C(1)	Inclination x 0.01745	
P(I,5)=P(I,5)*C(1)	Initial true anomaly x 0.01745	
P(I,9)=sin i	i, inclination	
P(I,10)=cos i		
P(I,11)=sin Ω	Ω, right ascension of node	
P(I,12)=cos Ω		

P(I,21)=a, orbit semi-major axis in feet

SAA=earth synchronous satellite radius in feet

P(I,23)=ratio of synchronous radius to orbit semi-major axis

P(I,6)=$a(1-e^2)$	e, eccentricity
P(I,7)= $\sqrt{\mu/[a(1-e^2)]}$	μ, gravitational constant
P(I,8)= $\sqrt{\mu/[a^2(1-e^2)]}$	

POINT(LONG,LAT,TID,UPV)

POINT(ALO,ALA,TIM,VEC)	ALO, longitude
	ALA, latitude
	TIM, time in days
	VEC, vector from the center of the earth to a user at a specific latitude and longitude

EW=long(rad)+2π(time)

SN=lat(rad)

Table 2 (continued)

VEC(1)=(radius of the earth at the equator)(cos lat)(cos long)

VEC(2)=(radius of the earth at the equator)(cos lat)(sin long)

VEC(3)=(radius of the earth at the equator)(sin lat)

<u>COVNAV(G,NSGD,4 SIGT)</u>

COVNAV(G,ID,NAT,SIG)	G, direction cosine matrix
	ID, index of the navsats which were chosen as the "best" four
	NAT, the number of them (always four)
	SIG, dilution of precision parameters returned to MAIN

This subroutine is the only one which requires a local system subroutine--a matrix inversion. This subroutine calculates $[G^TG]^{-1}$ and returns the values in SIG(1-6), which are the DOPs.

<u>TRMATX(TRANS,I)</u>

TRMATX(TR,I)	TR, 3 x 3 coordinate transformation matrix
	I, satellite number

TR(1,1)=cos Ω cos u - sin Ω cos i sin u   u, argument of latitude

TR(1,2)=-cos Ω sin u - sin Ω cos i cos u

TR(1,3)=sin Ω sin i

TR(2,1)=sin Ω cos u + cos Ω cos i sin u

TR(2,2)=-sin Ω sin u + cos Ω cos i cos u

TR(2,3)=-cos Ω sin i

TR(3,1)=sin i sin u

TR(3,2)=sin i cos u

TR(3,3)=cos i

<u>MATMUL(TRANS,Q,R)</u>

<u>MATMUL(TRANS,QEL,VEL)</u>

Table 2 (continued)

MATMUL(TRANS,QC,AC)

MATMUL(T,V,O)	T, 3 x 3 coordinate transformation matrix
	V, vector to be transformed
	O, vector returned

VOLUME(USUV,ISIC,VOLUM)

VOLUME(UVEC,IDSAT,VOL)	UVEC, unit vector from the user to each navsat in view
	IDSAT, index of the navsat
	VOL, volume of the tetrahedron formed by the set of four satellites used

ORBIT(N,TID,PER,RF,VE,AA)

ORBIT(I,T,PER,R,VEL,AC)	N, I, satellite number
	TID, T, time in days
	PER, period of a satellite
	RF, R, vector to a satellite from the center of the earth
	VE, VEL, velocity } not used at present
	AA, AC, acceleration due to gravity } not used at present

This subroutine iterates for the eccentric anomaly and computes the true anomaly. If time = 0, the following is computed:

V(I)=OP(I,5)=v, true anomaly

SINE= $[\sqrt{1-e^2}\ \sin v]/[1 + e \cos v]$, sin E

E(I)=E, arcsin E, eccentric anomaly

BIGT(I)=time from perigee for satellite

If time > 0, E(I) is obtained by iterating, then the following is computed:

SINV= $[\sqrt{1-e^2}\ \sin E]/[1 - e \cos E] = \sin v$

V(I)=arcsin v, true anomaly

U(I)=V(I)+OP(I,2), v + argument of periapsis = v + w = u, argument of latitude

Table 2 (continued)

OP(I,13) = cos u

OP(I,14) = sin u

OP(I,15) = latitude

OP(I,18) = u, argument of latitude

$$\left.\begin{aligned} Q(1) &= [a(1-e^2)/[1 + e\cos v] \\ Q(2) &= 0 \\ Q(3) &= 0 \end{aligned}\right\} \text{for calculating R}$$

$$\left.\begin{aligned} QEL(1) &= e \sin v \sqrt{\mu}\Big/\sqrt{a(1-e^2)} \\ QEL(2) &= \sqrt{\mu}\Big/\sqrt{a(1-e^2)} \\ QEL(3) &= 0 \end{aligned}\right\} \text{for calculating VEL}$$

$$\left.\begin{aligned} QC(1) &= (1 + e\cos v)^2\ \mu\Big/[a^2(1-e^2)^2] \\ QC(2) &= 0 \\ QC(3) &= 0 \end{aligned}\right\} \text{for calculating AC}$$

OP(I,24) = earth rotation

OP(I,16) = longitude of the satellite

TAAT(NSS,KCOM,KXX)

TAAT(MAX,MXX,MATRIX) MAX, 1 less than the number of navsats to be examined for use

MXX, the number of combinations of those navsats

MATRIX, contains indices of the navsats to be examined, three at a time

This subroutine sets up the sequence of navsats which are to be examined, using either the one above or below the user as one of the four in each calculation of the tetrahedron volume.

TALL(KOT,KCOM,KXX)

TALL(MAX,MXX,MATRIX) MAX, the number of navsats to be examined for use

MXX, the number of combinations of those navsats

Table 2 (continued)

MATRIX, contains indices of the navsats
to be examined, four at a time

This subroutine sets up the sequence of navsats which are to be examined, using all satellites taken four at a time.

BLOCK DATA

Contains various parameter values used in the program, although not all of them are used in the current version.

VECTOR(V1,I,V2,V3)

This subroutine performs vector additions, subtractions, and cross products.

UNIVEC(U,UV)

This subroutine calculates unit vectors.

DOT(V1,V2)

This function subprogram calculates dot products.

Table 3

INPUT CARD SETUP

All Cases; Case Type, and Navsat System Description

Card Number	Format	Variable Names	Explanation	Units
1	10I5	LOC	LOC, case type	
		NJL	NJL, number of navsats (maximum of 36)	
		ISCMP	Navsat combination switch ("zenith"/nadir plus 3 others, ISCMP = 0, or all combinations of 4, ISCMP = 1)	
2, etc.	12F6.0	P(N,1)[a]	Eccentricity	deg
	12F6.0	P(N,2)	Argument of perigee	deg
	12F6.0	P(N,3)	Right ascension	deg
	12F6.0	P(N,4)	Inclination	deg
	12F6.0	P(N,5)	Initial true anomaly	deg
n	12F6.0	PER(N)	Period	hr

[a]N is the number of the navsat; the first orbital element for all navsats is read in (eccentricity), then the second orbital element for all satellites is read in, etc. If there are more than 12 satellites, the next cards in sequence contain the rest of that element until NJL is reached. From here on, the cards differ depending on case.

Case I, Satellite User

n+1	12F6.0	P(NJL+1,K)	NJL+1, number of the user satellite; K = 1, 5, indices of elements of the user satellite (as above, in sequence)	deg
n+2	7F10.0	PER(NJL+1)	PER, period of the user satellite	hr
		AIN	AIN, antenna half beamwidth for the navsats	deg
		C	C, numerical constant for navsat selection[b]	
n+3	10I5	INC	INC, time step	min
		ITF	ITF, total number of time steps, plus 1	

[b]See Appendix A.

Table 3 (continued)

Case II, User at Specified Latitude and Longitude

Card Number	Format	Variable Names	Explanation	Units
n+1	7F10.0	ATL	ATL, latitude	deg
		ONGL	ONGL, longitude	deg
		ELEVAT	ELEVAT, masking angle above horizontal	deg
n+2	10I5	INC	INC, time increment per step	min
		ITF	ITF, total number of time steps, plus 1	

Case III, Global Calculations

Card Number	Format	Variable Names	Explanation	Units
n+1	7F10.0	LATDEG	LATDEG, latitude step (10 or 5 only)[c]	deg
		ELEVAT	ELEVAT, masking angle above horizontal	deg
n+2	10I5	LATIC	LATIC, latitude increment	
		LONIC	LONIC, longitude increment	
		INC	INC, time increment per step	min
		ITF	ITF, total number of time steps, plus 1	
		IPFREQ	IPFREQ, "DOP" print flag	
		ITIME	ITIME, print increments for DOP	

[c]The basic *longitude* step is always 10 deg. LATDEG = 10 is for northern *and* southern hemisphere coverage; LATDEG = 5 is for northern hemisphere coverage.

Table 4

COMPUTING COSTS (IBM 370/158 COMPUTER)

Case I, Satellite User

Number of Navsats	Choice [a]	Number of Time Steps	CPU Time (sec)	Amount of Core (bytes)	Costs [b] (MUs)
24	All	48	223	300 K	27.24
24	Zenith/nadir	48	21	300 K	2.68
36	All	57	348	722 K	42.70
36	Zenith/nadir	120	67	300 K	8.31

Case II, Single Earth-Based User

Number of Navsats	Choice [a]	Number of Time Steps	CPU Time (sec)	Amount of Core (bytes)	Costs [b] (MUs)
24	All	144	25	300 K	3.91
24	Zenith	144	21	300 K	2.69

Case III, Global Net of Earth-Based Users

Number of Navsats	Choice [a]	Number of Time Steps	CPU Time (sec)	Amount of Core (bytes)	Costs [b] (MUs)
24	Zenith	5	1228	300 K	149.29

[a]"All" refers to using all navsats in view, 4 at a time, in all calculations; zenith/nadir refers to using the navsat most directly above or below as one of the 4 in all calculations.

[b]Cost in Machine Units--a direct measure of computing cost used at Rand, which accounts for core, CPU time, and input/output resources used for a given run; currently, a Machine Unit (MU) costs about $1.25.

IV. PROGRAM INPUT AND OUTPUT

Table 5 (pages 32-36) is a listing of the input data set for a Case I run (using the navsat most nearly above or below the user in all calculations) and its resulting output. This run treats the user satellite as a very high apogee ballistic missile. Table 6 (pages 37-43) is a listing of the input data set for a Case II run (using all navsats in view, taken four at a time) and its resulting output. Table 7 (pages 44-55) is a listing of the input data set for a global distribution of earth-based users with its output.

Table 5

EXAMPLE: DATA SET FOR CASE I ("ZENITH/NADIR" SATELLITE USED)

INPUT

```
   1   24                                                                   CASE NO. OF SATELLITES SWITCH
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     ECCENTRICITY
    0     0     0     0     0     0     0     0     0     0     0     0
    0     0     0     0     0     0     0     0     0     0     0     0     ARGUMENT OF PERIGEE
    0     0     0     0     0     0     0     0   120   120   120   120
  120   120   120   120   240   240   240   240   240   240   240   240     RIGHT ASCENSION
   63    63    63    63    63    63    63    63    63    63    63    63
   63    63    63    63    63    63    63    63    63    63    63    63     INCLINATION
    0    45    90   135   180   225   270   315    15    60   105   150
  195   240   285   330    30    75   120   165   210   255   300   345     INITIAL TRUE ANOMALY
   12    12    12    12    12    12    12    12    12    12    12    12
   12    12    12    12    12    12    12    12    12    12    12    12     PERIOD OF NAVSATS
.81602 11.24  47.5144.21 69.76                                              USER PARAMETERS
11.0529       180.     .34                                                  PERIOD OF USER  BEAM  C
   10  100                                                                  INCREMENT  TOTAL TIME
```

Table 5 (Continued)

ORBITAL ELEMENTS

	ECC	ARGP	RASC	INC	ANCM[a]	PER
1	0.0	0.0	0.0	63.00	0.0	12.00
2	0.0	0.0	0.0	63.00	45.00	12.00
3	0.0	0.0	0.0	63.00	90.00	12.00
4	0.0	0.0	0.0	63.00	135.00	12.00
5	0.0	0.0	0.0	63.00	180.00	12.00
6	0.0	0.0	0.0	63.00	225.00	12.00
7	0.0	0.0	0.0	63.00	270.00	12.00
8	0.0	0.0	0.0	63.00	315.00	12.00
9	0.0	0.0	120.00	63.00	15.00	12.00
10	0.0	0.0	120.00	63.00	60.00	12.00
11	0.0	0.0	120.00	63.00	105.00	12.00
12	0.0	0.0	120.00	63.00	150.00	12.00
13	0.0	0.0	120.00	63.00	195.00	12.00
14	0.0	0.0	120.00	63.00	240.00	12.00
15	0.0	0.0	120.00	63.00	285.00	12.00
16	0.0	0.0	120.00	63.00	330.00	12.00
17	0.0	0.0	240.00	63.00	30.00	12.00
18	0.0	0.0	240.00	63.00	75.00	12.00
19	0.0	0.0	240.00	63.00	120.00	12.00
20	0.0	0.0	240.00	63.00	165.00	12.00
21	0.0	0.0	240.00	63.00	210.00	12.00
22	0.0	0.0	240.00	63.00	255.00	12.00
23	0.0	0.0	240.00	63.00	300.00	12.00
24	0.0	0.0	240.00	63.00	345.00	12.00

USER SATELLITE ORBITAL ELEMENTS

25	0.82	11.24	47.50	144.21	69.76	11.05

TOTAL TIME(MIN) = 990
TIME INCREMENT(MIN) = 10
BEAMWIDTH ANGLE(DEG) = 180.00
FRACTION OF NAVSAT SPHERICAL AREA = 0.340

THE SATELLITE MOST NEARLY ABOVE OR BELOW IS USED AS ONE OF THE FOUR IN ALL CALCULATIONS OF THE VOLUME OF THE TETRAHEDRON

[a]During final preparation of this report, the authors were informed by the NAVSTAR/GPS Joint Program Office that the planned orbital configuration for GPS had been changed. Users who wish to simulate the currently planned configuration should interchange the anomalies of satellites 9 through 16 with those of satellites 17 through 24, shown above. No other changes are required.

Table 5 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
10	1894.	0.829	1.423	1.165	0.516	1.647	1.726	12 3 5 14 4 6 7 20 23
20	3612.	0.926	1.339	1.061	0.521	1.628	1.709	17 3 8 23 1 2 4 5 6 7 9 14 19
30	5173.	0.967	1.338	1.042	0.533	1.650	1.734	17 3 8 23 1 2 4 5 6 7 9 14 19
40	6584.	1.736	1.394	1.088	0.716	2.226	2.339	16 10 12 23 5 6 13 18
50	7879.	1.674	1.231	0.901	0.837	2.078	2.240	21 10 12 23 4 5 6 17 18
60	9063.	1.792	1.219	0.909	0.972	2.167	2.375	15 10 12 23 4 5 6 11 17
70	10157.	1.937	1.254	0.966	1.116	2.308	2.564	15 10 12 23 4 5 6 11 17
80	11170.	1.698	1.627	1.307	1.048	2.352	2.574	19 12 23 24 4 5 10 11 17
90	12109.	2.432	1.404	1.145	1.563	2.808	3.214	15 10 12 23 4 5 11 17 22 24
100	12982.	2.735	1.823	1.548	1.887	3.287	3.790	20 10 11 23 4 5 17 22 24
110	13795.	3.528	1.534	1.143	2.557	3.847	4.619	20 9 11 22 4 5 10 23 24
120	14551.	3.882	1.545	1.171	2.856	4.178	5.061	20 9 11 22 3 4 5 10 23 24
130	15256.	4.564	1.635	1.224	3.377	4.848	5.908	18 9 11 22 3 4 5 10 24
140	15912.	4.404	1.678	1.298	3.395	4.713	5.809	18 3 5 10 4 9 11 22 24
150	16521.	4.494	1.673	1.228	3.533	4.796	5.956	18 3 5 10 4 9 11 22 23 24
160	17087.	4.606	1.702	1.229	3.685	4.910	6.139	18 3 5 10 4 9 11 21 22 23 24
170	17611.	4.973	1.799	1.392	4.009	5.288	6.636	19 3 5 10 4 9 11 21 22 23 24
180	18094.	5.600	1.830	1.347	4.583	5.891	7.464	19 3 5 23 4 9 10 21
190	18539.	6.115	1.848	1.307	5.015	6.388	8.122	19 2 10 21 3 4 5 9 16 23
200	18947.	6.918	1.859	1.384	5.697	7.164	9.153	7 2 4 10 3 9 16 21 23
210	19320.	6.464	1.970	1.563	5.345	6.757	8.616	17 2 4 23 3 9 10 16 21
220	19657.	6.328	1.961	1.550	5.283	6.625	8.474	17 2 4 23 3 9 10 16 21
230	19960.	6.232	1.942	1.497	5.243	6.528	8.373	17 2 4 9 3 10 16 20 21 23
240	20230.	6.188	1.923	1.408	5.242	6.480	8.334	17 2 4 9 3 10 16 20 23
250	20468.	6.738	1.938	1.402	5.714	7.011	9.045	18 2 4 9 3 10 16 20 22 23

Table 5 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
260	20674.	7.411	1.996	1.521	6.297	7.675	9.928	18 2 4 9 3 16 20 22
270	20848.	7.915	2.005	1.467	6.763	8.165	10.603	7 2 4 22 1 3 9 15 16 20
280	20991.	7.952	2.042	1.508	6.817	8.210	10.671	6 2 4 22 1 3 9 15 16 20
290	21103.	7.883	2.115	1.677	6.768	8.162	10.603	6 1 3 22 2 4 9 15 16 20
300	21184.	7.611	2.101	1.676	6.531	7.895	10.246	6 1 3 22 2 9 15 16 19 20
310	21236.	6.875	2.080	1.648	5.921	7.183	9.308	17 1 3 22 2 9 15 16 19
320	21257.	6.860	2.064	1.595	5.908	7.164	9.286	24 1 3 16 2 15 19 21 22
330	21247.	7.315	2.049	1.514	6.282	7.596	9.858	6 1 3 16 15 19 21 22
340	21208.	7.383	2.049	1.482	6.349	7.662	9.951	6 1 3 21 15 16 19
350	21138.	7.306	2.025	1.473	6.285	7.581	9.848	6 1 3 21 2 8 14 15 16 19
360	21038.	7.484	2.033	1.477	6.452	7.755	10.086	6 1 3 21 2 8 14 15 16 19
370	20907.	7.427	2.046	1.512	6.436	7.704	10.038	5 1 3 21 2 8 14 15 16 19
380	20745.	6.979	2.123	1.696	6.012	7.294	9.453	24 2 8 21 1 3 14 15 18 19
390	20551.	6.878	2.109	1.704	5.887	7.194	9.296	5 2 8 21 14 15 18 19 20
400	20326.	6.649	2.072	1.516	5.670	6.965	8.981	5 2 8 20 14 15 18 21
410	20069.	7.104	1.939	1.386	5.979	7.364	9.485	24 2 8 20 14 15 18
420	19778.	7.473	1.928	1.382	6.217	7.717	9.910	24 2 8 20 14 18
430	19454.	6.749	1.893	1.365	5.606	7.010	8.976	4 8 18 20 2 14
440	19095.	5.615	1.906	1.393	4.694	5.930	7.563	5 8 18 20 2 7
450	18701.	5.890	1.936	1.449	4.906	6.200	7.906	23 8 18 20 1 2 7 19
460	18270.	5.728	1.971	1.610	4.761	6.058	7.705	4 7 18 20 1 2 8 17 19
470	17801.	5.229	1.781	1.290	4.267	5.524	6.980	22 7 17 19 1 2 8 18 20
480	17293.	4.602	1.718	1.219	3.679	4.913	6.137	22 7 17 19 1 18
490	16744.	4.722	1.664	1.206	3.639	5.006	6.189	5 7 17 19 1 18
500	16151.	4.532	1.617	1.203	3.398	4.812	5.891	5 7 17 19 1 18

Table 5 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
510	15514.	3.589	1.574	1.204	2.700	3.919	4.759	22 7 17 19 1 8 18
520	14629.	3.356	1.537	1.205	2.468	3.691	4.440	22 7 17 19 1 8 18
530	14093.	2.933	1.507	1.102	2.032	3.297	3.873	3 7 17 18 1 8 19 24
540	13303.	2.526	1.479	1.109	1.687	2.927	3.378	3 7 17 18 1 6 8 24
550	12453.	2.363	1.339	0.955	1.546	2.716	3.126	21 7 18 24 1 6 8 17
560	11541.	1.995	1.306	0.980	1.225	2.385	2.681	4 7 18 24 6 8 17
570	10558.	2.234	1.335	1.014	1.305	2.603	2.912	4 6 18 24 8 10 11 17
580	9496.	1.750	1.389	1.135	0.870	2.235	2.398	21 6 17 24 8 9 10 11 18 23
590	8347.	1.430	1.338	1.088	0.679	1.958	2.073	20 6 17 24 8 9 10 11 18 23
600	7095.	1.615	1.256	0.916	0.683	2.046	2.157	2 6 17 23 8 9 10 11
610	5733.	1.403	1.178	0.841	0.695	1.832	1.959	2 11 17 23 5 6 8 9 10 16
620	4228.	1.128	1.214	0.947	0.556	1.657	1.748	2 10 17 23 5 6 8 9 11 16 22
630	2576.	1.120	1.140	0.816	0.521	1.598	1.681	14 5 22 24 6 7 8 10 16 17
640	784.	0.902	1.376	1.099	0.512	1.645	1.723	9 1 4 17 11

TERMINATION OF RUN, ALTITUDE APPROCHING ZERO*

*Satellite user calculations terminate when and if the orbit intersects the earth's surface.

Table 6

EXAMPLE: DATA SET FOR CASE II (ALL SATELLITES, FOUR AT A TIME)

INPUT

2	24	1										CASE NO. OF SATELLITES SWITCH
0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	ECCENTRICITY
0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	ARGUMENT OF PERIGEE
0	0	0	0	0	0	0	0	120	120	120	120	
120	120	120	120	240	240	240	240	240	240	240	240	RIGHT ASCENSION
63	63	63	63	63	63	63	63	63	63	63	63	
63	63	63	63	63	63	63	63	63	63	63	63	INCLINATION
0	45	90	135	180	225	270	315	15	60	105	150	
195	240	285	330	30	75	120	165	210	255	300	345	INITIAL TRUE ANOMALY
12	12	12	12	12	12	12	12	12	12	12	12	
12	12	12	12	12	12	12	12	12	12	12	12	PERIOD OF NAVSATS
0.		0.	5.									LATITUDE LONGITUDE ELEVATION
6	121											INCREMENT TOTAL TIME

Table 6 (Continued)

ORBITAL ELEMENTS

	ECC	ARGP	RASC	INC	ANOM	PER
1	0.0	0.0	0.0	63.00	0.0	12.00
2	0.0	0.0	0.0	63.00	45.00	12.00
3	0.0	0.0	0.0	63.00	90.00	12.00
4	0.0	0.0	0.0	63.00	135.00	12.00
5	0.0	0.0	0.0	63.00	180.00	12.00
6	0.0	0.0	0.0	63.00	225.00	12.00
7	0.0	0.0	0.0	63.00	270.00	12.00
8	0.0	0.0	0.0	63.00	315.00	12.00
9	0.0	0.0	120.00	63.00	15.00	12.00
10	0.0	0.0	120.00	63.00	60.00	12.00
11	0.0	0.0	120.00	63.00	105.00	12.00
12	0.0	0.0	120.00	63.00	150.00	12.00
13	0.0	0.0	120.00	63.00	195.00	12.00
14	0.0	0.0	120.00	63.00	240.00	12.00
15	0.0	0.0	120.00	63.00	285.00	12.00
16	0.0	0.0	120.00	63.00	330.00	12.00
17	0.0	0.0	240.00	63.00	30.00	12.00
18	0.0	0.0	240.00	63.00	75.00	12.00
19	0.0	0.0	240.00	63.00	120.00	12.00
20	0.0	0.0	240.00	63.00	165.00	12.00
21	0.0	0.0	240.00	63.00	210.00	12.00
22	0.0	0.0	240.00	63.00	255.00	12.00
23	0.0	0.0	240.00	63.00	300.00	12.00
24	0.0	0.0	240.00	63.00	345.00	12.00

USER LOCATION ON EARTH
LATITUDE = 0.0 DEGREES
LONGITUDE = 0.0 DEGREES
MASKING ANGLE = 5.00 DEGREES

TOTAL TIME(MIN) = 720
TIME INCREMENT(MIN) = 6

ALL SATELLITES, TAKEN FOUR AT A TIME, ARE USED IN
THE CALCULATIONS OF THE VOLUME OF THE TETRAHEDRON

Table 6 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
0	0.	2.012	1.843	1.554	1.328	2.729	3.035	1 13 14 20 2 8 19
6	0.	1.954	1.810	1.513	1.251	2.664	2.943	1 13 19 20 2 8 14
12	0.	1.968	1.796	1.495	1.217	2.664	2.929	1 13 19 20 2 8 14
18	0.	1.994	1.744	1.437	1.195	2.649	2.905	1 2 13 20 8 14 19
24	0.	1.581	1.318	1.082	0.870	2.058	2.234	1 14 18 20 2 8 13 19
30	0.	1.631	1.343	1.118	0.885	2.113	2.291	1 14 18 20 2 8 13 19
36	0.	1.768	1.251	0.921	0.988	2.166	2.381	1 13 18 20 2 8 14 19
42	0.	1.858	1.227	0.875	1.002	2.226	2.442	1 13 18 20 2 8 14 19
48	0.	1.984	1.216	0.878	1.033	2.327	2.546	1 13 18 20 2 8 14 19
54	0.	1.883	1.181	0.895	0.904	2.223	2.400	7 8 18 20 1 2 13 14 19
60	0.	1.939	1.165	0.896	0.955	2.273	2.465	8 7 18 20 1 2 13 14 19
66	0.	1.824	1.317	0.958	0.860	2.249	2.408	8 2 7 20 1 13 14 18 19
72	0.	2.108	1.208	0.912	1.082	2.430	2.660	8 7 18 20 1 13 14 19
78	0.	2.223	1.237	0.945	1.160	2.546	2.797	8 13 18 20 1 7 14 19
84	0.	2.307	1.277	0.985	1.214	2.637	2.903	8 13 18 20 1 7 14 19
90	0.	2.447	1.336	1.034	1.296	2.788	3.074	8 13 18 20 1 7 14 19
96	0.	2.662	1.419	1.093	1.414	3.016	3.331	8 13 18 20 1 7 14 19
102	0.	2.981	1.536	1.168	1.586	3.354	3.710	8 13 18 20 1 7 14 19
108	0.	3.082	1.420	1.010	1.599	3.394	3.751	1 7 14 19 8 13 18 20
114	0.	2.751	1.328	0.972	1.428	3.055	3.372	1 7 14 19 8 13 18 20
120	0.	2.527	1.266	0.940	1.311	2.826	3.115	1 7 14 19 8 13 18 20
126	0.	2.379	1.225	0.914	1.230	2.676	2.945	1 7 14 19 8 13 18 20
132	0.	2.290	1.200	0.893	1.177	2.585	2.840	1 7 14 19 8 13 18 20
138	0.	1.878	1.267	0.897	0.859	2.265	2.423	19 7 17 20 1 8 13 14 18
144	0.	1.866	1.274	1.017	0.862	2.259	2.418	18 7 17 20 1 8 13 14 19

Table 6 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
150	0.	1.939	1.261	0.949	0.955	2.313	2.503	18 7 14 17 1 8 13 19
156	0.	1.947	1.266	0.937	0.992	2.334	2.536	18 7 14 17 1 8 13 19
162	0.	1.954	1.280	0.957	1.044	2.335	2.558	18 1 7 14 8 13 17 19
168	0.	1.826	1.266	0.933	1.014	2.235	2.454	18 1 7 14 8 13 17 19
174	0.	1.738	1.307	0.932	0.999	2.175	2.393	18 1 7 14 8 13 17 19
180	0.	1.992	1.509	1.184	1.137	2.499	2.745	18 7 14 17 8 13 19
186	0.	1.999	1.605	1.292	1.171	2.564	2.819	18 7 14 17 8 13 19
192	0.	2.003	1.720	1.416	1.206	2.640	2.902	18 7 14 17 8 13 19
198	0.	1.812	1.384	1.108	0.949	2.280	2.469	18 6 8 14 7 13 17 19
204	0.	1.701	1.325	1.049	0.903	2.156	2.338	18 6 8 14 7 13 17 19
210	0.	1.634	1.288	1.013	0.876	2.080	2.257	18 6 8 14 7 13 17 19
216	0.	1.602	1.267	0.995	0.864	2.043	2.218	18 6 8 14 7 13 17 19
222	0.	1.604	1.262	0.994	0.864	2.041	2.217	18 6 8 14 7 12 13 17 19
228	0.	1.639	1.270	1.007	0.878	2.074	2.252	18 6 8 14 7 12 13 17 19
234	0.	1.709	1.293	1.035	0.905	2.143	2.326	18 6 8 14 7 12 13 17 19
240	0.	1.731	1.267	0.971	0.989	2.146	2.363	18 7 12 14 6 8 13 17 19
246	0.	1.779	1.284	1.034	0.900	2.194	2.371	18 6 8 19 7 12 13 14 17
252	0.	1.769	1.167	0.917	0.811	2.147	2.295	12 14 17 24 18 6 7 8 13 19
258	0.	1.748	1.231	0.977	0.811	2.138	2.287	18 6 8 19 7 12 13 14 17 24
264	0.	1.747	1.212	0.957	0.774	2.126	2.262	6 8 18 19 17 7 12 13 14 24
270	0.	1.885	1.231	0.959	0.949	2.251	2.443	17 12 14 24 6 7 8 13 18
276	0.	1.749	1.270	1.034	0.907	2.161	2.344	17 6 12 14 7 8 13 18 24
282	0.	1.677	1.249	1.004	0.881	2.091	2.269	17 6 12 14 7 8 13 18 24
288	0.	1.642	1.241	0.989	0.868	2.058	2.233	17 6 12 14 7 8 13 18 24
294	0.	1.640	1.245	0.990	0.867	2.059	2.234	17 6 12 14 7 8 13 18 24

Table 6 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
300	0.	1.672	1.264	1.006	0.880	2.096	2.273	17 6 12 14 7 8 13 18 24
306	0.	1.741	1.299	1.042	0.907	2.172	2.354	17 6 12 14 7 8 13 18 24
312	0.	1.855	1.353	1.101	0.953	2.296	2.486	17 6 12 14 7 8 13 18 24
318	0.	1.947	1.373	1.115	0.971	2.382	2.573	17 6 14 18 7 8 12 13 24
324	0.	1.989	1.351	1.071	0.949	2.404	2.585	17 6 14 18 7 8 12 13 24
330	0.	2.033	1.336	1.033	0.926	2.433	2.603	17 6 14 18 7 8 12 13 24
336	0.	2.082	1.330	0.999	0.900	2.471	2.630	17 6 14 18 7 12 13 24
342	0.	1.781	1.386	1.056	1.036	2.257	2.483	17 6 11 13 7 12 18 24
348	0.	1.903	1.391	1.093	1.068	2.357	2.588	17 6 11 13 7 12 18 24
354	0.	1.919	1.331	1.005	1.005	2.335	2.543	17 6 13 18 7 11 12 24
360	0.	2.431	1.255	1.001	1.174	2.736	2.977	7 11 13 24 17 12 18
366	0.	1.919	1.331	1.005	1.005	2.335	2.542	12 8 11 24 7 13 17 18
372	0.	1.903	1.391	1.093	1.069	2.357	2.588	12 8 18 24 7 11 13 17
378	0.	1.782	1.386	1.056	1.037	2.257	2.484	12 8 18 24 7 11 13 17
384	0.	2.082	1.330	0.999	0.900	2.471	2.630	12 8 11 23 7 13 17 24
390	0.	2.033	1.336	1.032	0.926	2.433	2.603	12 8 11 23 6 7 13 17 24
396	0.	1.989	1.351	1.071	0.949	2.404	2.585	12 8 11 23 6 7 13 17 24
402	0.	1.947	1.373	1.114	0.971	2.382	2.573	12 8 11 23 6 7 13 17 24
408	0.	1.855	1.354	1.101	0.953	2.296	2.486	12 8 17 23 6 7 11 13 24
414	0.	1.742	1.299	1.042	0.907	2.172	2.354	12 8 17 23 6 7 11 13 24
420	0.	1.672	1.264	1.006	0.880	2.096	2.273	12 8 17 23 6 7 11 13 24
426	0.	1.640	1.245	0.990	0.867	2.059	2.234	12 8 17 23 6 7 11 13 24
432	0.	1.642	1.240	0.989	0.868	2.058	2.233	12 8 17 23 6 7 11 13 24
438	0.	1.677	1.249	1.004	0.880	2.091	2.269	12 8 17 23 6 7 11 13 24
444	0.	1.748	1.270	1.034	0.906	2.161	2.343	12 8 17 23 6 7 11 13 24

Table 6 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
450	0.	1.885	1.232	0.959	0.949	2.252	2.443	12 13 17 23 6 7 8 11 24
456	0.	1.747	1.212	0.957	0.774	2.126	2.262	6 8 10 11 12 7 13 17 23 24
462	0.	1.748	1.231	0.977	0.811	2.138	2.287	11 6 8 10 7 12 13 17 23 24
468	0.	1.789	1.187	0.917	0.811	2.147	2.295	12 13 17 23 11 6 7 8 10 24
474	0.	1.779	1.284	1.034	0.900	2.194	2.371	11 6 8 10 7 12 17 23 24
480	0.	1.731	1.267	0.971	0.989	2.146	2.363	11 7 17 23 6 8 10 12 24
486	0.	1.709	1.293	1.035	0.905	2.143	2.326	11 6 8 23 7 10 12 17 24
492	0.	1.639	1.270	1.007	0.878	2.074	2.252	11 6 8 23 7 10 12 17 24
498	0.	1.605	1.262	0.994	0.865	2.041	2.217	11 6 8 23 7 10 12 17 24
504	0.	1.602	1.267	0.995	0.864	2.043	2.218	11 6 8 23 7 10 12 24
510	0.	1.633	1.288	1.013	0.876	2.080	2.257	11 6 8 23 7 10 12 24
516	0.	1.701	1.325	1.049	0.903	2.156	2.338	11 6 8 23 7 10 12 24
522	0.	1.812	1.384	1.108	0.949	2.280	2.469	11 6 8 23 7 10 12 24
528	0.	2.003	1.720	1.416	1.206	2.640	2.903	11 7 12 23 6 10 24
534	0.	2.000	1.605	1.292	1.171	2.564	2.819	11 7 12 23 6 10 24
540	0.	1.992	1.509	1.184	1.137	2.499	2.746	11 7 12 23 6 10 24
546	0.	1.738	1.307	0.933	0.999	2.175	2.393	11 5 7 23 6 10 12 24
552	0.	1.828	1.286	0.933	1.014	2.235	2.454	11 5 7 23 6 10 12 24
558	0.	1.953	1.279	0.957	1.044	2.335	2.558	11 5 7 23 6 10 12 24
564	0.	1.947	1.286	0.937	0.992	2.334	2.535	11 7 12 23 5 6 10 24
570	0.	1.939	1.261	0.949	0.955	2.313	2.503	11 7 12 23 5 6 10 24
576	0.	1.866	1.274	1.017	0.862	2.259	2.418	11 7 9 12 5 6 10 23 24
582	0.	1.877	1.267	0.897	0.859	2.265	2.422	10 7 9 12 5 6 11 23 24
588	0.	2.290	1.200	0.893	1.177	2.585	2.841	5 7 10 23 6 9 11 24
594	0.	2.379	1.225	0.914	1.230	2.675	2.945	5 7 10 23 6 9 11 24

Table 6 (Continued)

TIME(MN)	ALT(NM)	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP	SATELLITES CHOSEN
600	0.	2.527	1.266	0.940	1.311	2.826	3.115	5 7 10 23 6 9 11 24
606	0.	2.750	1.326	0.971	1.428	3.054	3.371	5 7 10 23 6 9 11 24
612	0.	3.081	1.420	1.010	1.598	3.393	3.750	5 7 10 23 6 9 11 24
618	0.	2.982	1.536	1.169	1.587	3.354	3.711	6 9 11 24 5 7 10 23
624	0.	2.662	1.419	1.093	1.414	3.017	3.332	6 9 11 24 5 7 10 23
630	0.	2.448	1.336	1.034	1.296	2.789	3.075	6 9 11 24 5 7 10 23
636	0.	2.308	1.278	0.985	1.214	2.638	2.904	6 9 11 24 5 7 10 23
642	0.	2.225	1.237	0.945	1.160	2.546	2.798	6 9 11 24 5 7 10 23
648	0.	2.109	1.208	0.912	1.083	2.431	2.661	6 7 9 11 5 10 23 24
654	0.	1.824	1.317	0.958	0.860	2.249	2.408	6 4 7 9 5 10 11 23 24
660	0.	1.939	1.165	0.896	0.955	2.273	2.465	6 7 9 11 4 5 10 23 24
666	0.	1.884	1.181	0.895	0.904	2.223	2.400	6 7 9 11 5 4 10 23 24
672	0.	1.984	1.215	0.878	1.032	2.327	2.545	5 9 11 24 4 6 10 23
678	0.	1.658	1.227	0.875	1.002	2.227	2.442	5 9 11 24 4 6 10 23
684	0.	1.769	1.251	0.921	0.988	2.166	2.381	5 9 11 24 4 6 10 23
690	0.	1.631	1.344	1.118	0.885	2.113	2.291	5 9 11 23 4 6 10 24
696	0.	1.581	1.318	1.082	0.870	2.058	2.234	5 9 11 23 4 6 10 24
702	0.	1.994	1.744	1.437	1.195	2.649	2.906	5 4 9 24 6 10 23
708	0.	1.969	1.796	1.495	1.217	2.664	2.929	5 9 10 24 4 6 23
714	0.	1.954	1.810	1.513	1.251	2.663	2.943	5 9 10 24 4 6 23
720	0.	2.012	1.843	1.554	1.328	2.729	3.035	5 9 23 24 4 6 10

Table 7

EXAMPLE: DATA SET FOR CASE III ("ZENITH" SATELLITE USED IN ALL CALCULATIONS)*

INPUT

```
  3   24                                                                CASE NO. OF SATELLITES  SWITCH
  0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0             ECCENTRICITY
  0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0             ARGUMENT OF PERIGEE
  0    0    0    0    0    0    0    0  120  120  120  120
120  120  120  120  240  240  240  240  240  240  240  240             RIGHT ASCENSION
 63   63   63   63   63   63   63   63   63   63   63   63
 63   63   63   63   63   63   63   63   63   63   63   63             INCLINATION
  0   45   90  135  180  225  270  315   15   60  105  150
195  240  285  330   30   75  120  165  210  255  300  345             INITIAL TRUE ANOMALY
 12   12   12   12   12   12   12   12   12   12   12   12
 12   12   12   12   12   12   12   12   12   12   12   12             PERIOD OF NAVSATS
 5.       5.                                                           LATITUDE STEP  LONGITUDE STEP
  1    1  250    2    0    0                                           LATINC  LONGING  INC  TOTAL TIME
                                                                                 "DOP" FLAG  PRINGINT
```

*This example is contrived only to show what the global calculations output would look like. There are only two time points in this run--0 and 250 minutes. No "snapshot" calculations were made.

Table 7 (Continued)

ORBITAL ELEMENTS

	ECC	ARGP	RASC	INC	ANOM	PER
1	0.0	0.0	0.0	63.00	0.0	12.00
2	0.0	0.0	0.0	63.00	45.00	12.00
3	0.0	0.0	0.0	63.00	90.00	12.00
4	0.0	0.0	0.0	63.00	135.00	12.00
5	0.0	0.0	0.0	63.00	180.00	12.00
6	0.0	0.0	0.0	63.00	225.00	12.00
7	0.0	0.0	0.0	63.00	270.00	12.00
8	0.0	0.0	0.0	63.00	315.00	12.00
9	0.0	0.0	120.00	63.00	15.00	12.00
10	0.0	0.0	120.00	63.00	60.00	12.00
11	0.0	0.0	120.00	63.00	105.00	12.00
12	0.0	0.0	120.00	63.00	150.00	12.00
13	0.0	0.0	120.00	63.00	195.00	12.00
14	0.0	0.0	120.00	63.00	240.00	12.00
15	0.0	0.0	120.00	63.00	285.00	12.00
16	0.0	0.0	120.00	63.00	330.00	12.00
17	0.0	0.0	240.00	63.00	30.00	12.00
18	0.0	0.0	240.00	63.00	75.00	12.00
19	0.0	0.0	240.00	63.00	120.00	12.00
20	0.0	0.0	240.00	63.00	165.00	12.00
21	0.0	0.0	240.00	63.00	210.00	12.00
22	0.0	0.0	240.00	63.00	255.00	12.00
23	0.0	0.0	240.00	63.00	300.00	12.00
24	0.0	0.0	240.00	63.00	345.00	12.00

GLOBAL DISTRIBUTION CALCULATIONS

MASKING ANGLE = 5.00 DEGREES
LATITUDE STEP = 5.00 DEGREES
LATITUDE INCREMENT = 1
LONGITUDE INCREMENT = 1
DILUTION OF PRECISION PARAMETERS PRINTED AT TIME INCREMENT OF 0

TOTAL TIME(MIN) = 250
TIME INCREMENT(MIN) = 250

THE SATELLITE MOST NEARLY OVERHEAD IS USED AS ONE OF THE FOUR
IN ALL CALCULATIONS OF THE VOLUME OF THE TETRAHEDRON

Table 7 (Continued)

ELEVATION DISTRIBUTION - PROBABILITY THAT THE SATELLITE IN VIEW WILL HAVE ELEVATION ANGLES AS LISTED

ELEVATION ANGLE

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90
PROB	0.0	10.3	10.3	9.8	9.2	9.1	7.8	8.2	6.8	6.4	6.2	4.7	3.5	2.6	2.2	1.3	0.9	0.2

LATITUDE ELEVATION DISTRIBUTION
PROBABILITY THAT ANY SATELLITE IN VIEW WILL HAVE AN ELEVATION ANGLE GREATER THAN OR EQUAL TO THOSE LISTED

LATITUDE

ELEV ANGLE	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	0.94	0.92	0.91	0.92	0.90	0.90	0.91	0.90	0.87	0.88	0.86	0.90	0.90	0.90	0.88	0.87	0.88	0.85	0.83
15	0.83	0.85	0.84	0.82	0.82	0.82	0.81	0.77	0.75	0.78	0.78	0.78	0.80	0.78	0.79	0.77	0.76	0.72	0.71
20	0.78	0.77	0.76	0.75	0.73	0.73	0.69	0.66	0.66	0.67	0.69	0.69	0.70	0.70	0.68	0.66	0.64	0.60	0.56
25	0.72	0.69	0.67	0.66	0.65	0.62	0.58	0.56	0.57	0.60	0.60	0.61	0.61	0.60	0.60	0.56	0.53	0.48	0.47
30	0.61	0.61	0.59	0.57	0.54	0.50	0.49	0.49	0.50	0.52	0.52	0.53	0.53	0.51	0.49	0.46	0.42	0.40	0.37
35	0.56	0.52	0.51	0.48	0.42	0.42	0.42	0.42	0.43	0.45	0.46	0.45	0.45	0.44	0.41	0.36	0.35	0.32	0.32
40	0.39	0.43	0.40	0.36	0.35	0.35	0.35	0.35	0.37	0.38	0.38	0.38	0.38	0.34	0.31	0.29	0.28	0.25	0.25
45	0.33	0.34	0.29	0.27	0.28	0.28	0.30	0.31	0.31	0.33	0.33	0.31	0.30	0.27	0.25	0.22	0.21	0.21	0.19
50	0.28	0.20	0.20	0.20	0.22	0.23	0.24	0.25	0.26	0.26	0.27	0.26	0.22	0.19	0.18	0.17	0.16	0.16	0.17
55	0.06	0.10	0.13	0.16	0.17	0.18	0.19	0.20	0.21	0.21	0.21	0.18	0.16	0.16	0.14	0.13	0.13	0.12	0.12
60	0.0	0.02	0.07	0.10	0.12	0.14	0.15	0.16	0.16	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.10	0.09	0.09
65	0.0	0.0	0.02	0.07	0.08	0.11	0.11	0.13	0.12	0.13	0.10	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06
70	0.0	0.0	0.0	0.02	0.05	0.07	0.09	0.09	0.09	0.07	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
75	0.0	0.0	0.0	0.0	0.03	0.05	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.03
80	0.0	0.0	0.0	0.0	0.00	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
85	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.00	0.00	0.00

ACCUMULATIVE ELEVATION DISTRIBUTION
PROBABILITY THAT THE ELEVATION ANGLE IS GREATER THAN OR EQUAL TO THOSE LISTED

ELEVATION ANGLE

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
PROB	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT ALTITUDE DOP WILL BE GREATER THAN NUMBER LISTED

LATITUDE

NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.4	1.000	1.000	1.000	1.000	1.000	1.000	0.986	0.972	1.000	0.986	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.6	1.000	1.000	0.972	1.000	1.000	0.819	0.861	0.806	0.889	0.944	0.944	0.861	0.889	0.917	0.958	0.986	0.931	0.931	1.000
1.8	1.000	1.000	0.931	0.819	0.764	0.583	0.528	0.528	0.639	0.819	0.889	0.819	0.806	0.833	0.778	0.653	0.653	0.597	0.583
2.0	1.000	1.000	0.708	0.556	0.500	0.319	0.250	0.111	0.167	0.319	0.681	0.764	0.722	0.778	0.653	0.444	0.431	0.389	0.361
2.2	0.500	0.736	0.417	0.319	0.264	0.194	0.167	0.042	0.0	0.167	0.500	0.569	0.611	0.528	0.472	0.333	0.278	0.236	0.194
2.4	0.0	0.306	0.250	0.069	0.014	0.014	0.042	0.0	0.0	0.167	0.500	0.528	0.556	0.389	0.361	0.278	0.167	0.069	0.111
2.6	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.139	0.444	0.472	0.542	0.361	0.292	0.181	0.069	0.028	0.028
2.8	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.042	0.306	0.333	0.292	0.194	0.181	0.139	0.069	0.014	0.028
3.0	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.042	0.236	0.264	0.222	0.125	0.139	0.111	0.042	0.0	0.0
3.2	0.0	0.069	0.014	0.0	0.0	0.014	0.028	0.0	0.0	0.014	0.153	0.222	0.181	0.097	0.125	0.056	0.014	0.0	0.0
3.4	0.0	0.069	0.014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.069	0.167	0.111	0.042	0.014	0.014	0.014	0.0	0.0
3.6	0.0	0.069	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.069	0.083	0.0	0.0	0.0	0.0	0.0	0.0
3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.042	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT POSITION DOP IN HORIZONTAL PLANE WILL BE GREATER THAN NUMBER LISTED

LATITUDE

NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.2	1.000	1.000	1.000	0.917	0.986	1.000	1.000	1.000	1.000	0.986	0.944	0.958	1.000	0.986	0.972	0.958	0.944	0.972	1.000
1.4	1.000	0.389	0.250	0.319	0.444	0.431	0.472	0.542	0.528	0.667	0.694	0.736	0.764	0.542	0.444	0.319	0.208	0.278	0.250
1.6	1.000	0.319	0.042	0.0	0.0	0.097	0.306	0.181	0.236	0.319	0.458	0.472	0.389	0.333	0.264	0.125	0.111	0.097	0.083
1.8	0.500	0.236	0.042	0.0	0.0	0.0	0.014	0.014	0.0	0.139	0.278	0.194	0.111	0.125	0.125	0.056	0.014	0.014	0.028
2.0	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.069	0.153	0.056	0.028	0.0	0.028	0.014	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.014	0.014	0.0	0.0	0.0	0.014	0.014	0.0	0.0	0.0
2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT LARGER COMPONENT OF POSITION DOP WILL BE GREATER THAN NUMBER LISTED

LATITUDE

NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	0.653	0.431	0.611	0.861	0.875	0.944	0.806	0.667	0.764	0.778	0.806	0.806	0.667	0.611	0.556	0.486	0.597	0.694
1.2	1.000	0.319	0.042	0.0	0.083	0.292	0.333	0.278	0.389	0.514	0.514	0.556	0.583	0.417	0.347	0.194	0.125	0.208	0.250
1.4	0.833	0.264	0.042	0.0	0.0	0.028	0.167	0.069	0.111	0.222	0.375	0.250	0.125	0.097	0.153	0.056	0.042	0.028	0.056
1.6	0.278	0.125	0.042	0.0	0.0	0.0	0.0	0.014	0.0	0.083	0.139	0.097	0.083	0.014	0.056	0.014	0.0	0.0	0.0
1.8	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.042	0.083	0.056	0.028	0.0	0.028	0.014	0.0	0.0	0.0
2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.014	0.014	0.0	0.0	0.0	0.014	0.014	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT TIME DOP WILL BE GREATER THAN NUMBER LISTED

LATITUDE

NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	0.972	0.931	0.903	0.833	0.833	0.875	0.931	0.972	0.931	0.889	0.917	0.986	0.986	0.944	0.917	0.917	0.917
1.0	1.000	1.000	0.736	0.722	0.694	0.542	0.542	0.583	0.639	0.625	0.639	0.667	0.681	0.778	0.722	0.500	0.375	0.361	0.417
1.2	1.000	0.611	0.347	0.292	0.319	0.250	0.250	0.083	0.042	0.181	0.528	0.597	0.597	0.542	0.458	0.375	0.278	0.208	0.250
1.4	1.000	0.319	0.042	0.014	0.056	0.125	0.194	0.083	0.014	0.167	0.500	0.542	0.514	0.417	0.333	0.236	0.139	0.056	0.056
1.6	0.500	0.208	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.167	0.458	0.458	0.375	0.278	0.222	0.139	0.083	0.0	0.0
1.8	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.125	0.278	0.319	0.333	0.236	0.208	0.139	0.056	0.0	0.0
2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.083	0.097	0.014	0.014	0.014	0.028	0.014	0.0	0.0	0.0
2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT THREE DIMENSIONAL POSITION DOP WILL BE GREATER THAN NUMBER LISTED

LATITUDE

NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.0	1.000	1.000	1.000	1.000	1.000	0.944	0.917	0.917	0.972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.986	1.000
2.2	1.000	1.000	0.972	0.944	0.889	0.764	0.778	0.778	0.917	0.931	0.931	0.875	0.931	0.903	0.819	0.667	0.694	0.625	0.639
2.4	1.000	1.000	0.694	0.569	0.444	0.347	0.347	0.292	0.306	0.500	0.681	0.778	0.708	0.736	0.583	0.500	0.444	0.417	0.417
2.6	1.000	0.792	0.514	0.292	0.264	0.194	0.222	0.083	0.014	0.167	0.528	0.611	0.625	0.569	0.486	0.333	0.264	0.236	0.278
2.8	1.000	0.556	0.139	0.0	0.014	0.014	0.056	0.014	0.0	0.167	0.500	0.556	0.583	0.458	0.389	0.278	0.167	0.056	0.056
3.0	0.0	0.125	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.167	0.486	0.514	0.528	0.389	0.306	0.208	0.083	0.028	0.028
3.2	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.167	0.431	0.431	0.375	0.264	0.181	0.139	0.069	0.028	0.028
3.4	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.083	0.292	0.278	0.222	0.181	0.181	0.125	0.056	0.0	0.0
3.6	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.042	0.208	0.250	0.194	0.097	0.111	0.083	0.014	0.0	0.0
3.8	0.0	0.069	0.014	0.0	0.0	0.0	0.028	0.0	0.0	0.0	0.083	0.125	0.097	0.0	0.028	0.0	0.014	0.0	0.0
4.0	0.0	0.069	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.042	0.069	0.0	0.0	0.0	0.0	0.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.028	0.056	0.0	0.0	0.0	0.0	0.0	0.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION - ACCUMULATIVE LATITUDE DISTRIBUTION
PROBABILITY THAT FOUR DIMENSIONAL POSITION DOP WILL BE GREATER THAN NUMBER LISTED

	LATITUDE																		
NUM	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
0.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.2	1.000	1.000	0.972	1.000	1.000	0.931	0.917	0.917	0.944	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.986	0.972	0.944
2.4	1.000	1.000	0.972	0.944	0.861	0.681	0.750	0.764	0.889	0.931	0.875	0.861	0.861	0.875	0.847	0.681	0.694	0.625	0.639
2.6	1.000	1.000	0.694	0.569	0.458	0.347	0.333	0.292	0.347	0.500	0.639	0.778	0.694	0.764	0.694	0.500	0.417	0.417	0.361
2.8	1.000	0.792	0.542	0.431	0.431	0.319	0.250	0.083	0.014	0.167	0.528	0.611	0.653	0.625	0.528	0.403	0.306	0.264	0.306
3.0	1.000	0.556	0.278	0.208	0.236	0.167	0.208	0.083	0.014	0.167	0.500	0.569	0.583	0.458	0.389	0.278	0.236	0.181	0.194
3.2	0.500	0.319	0.042	0.0	0.014	0.014	0.056	0.014	0.0	0.167	0.500	0.542	0.556	0.431	0.333	0.250	0.111	0.056	0.056
3.4	0.0	0.153	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.167	0.486	0.514	0.500	0.361	0.278	0.181	0.083	0.028	0.028
3.6	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.167	0.472	0.472	0.431	0.319	0.250	0.167	0.069	0.0	0.0
3.8	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.153	0.389	0.292	0.250	0.194	0.181	0.125	0.056	0.0	0.0
4.0	0.0	0.069	0.014	0.0	0.0	0.014	0.042	0.0	0.0	0.056	0.236	0.250	0.167	0.069	0.139	0.097	0.028	0.0	0.0
4.2	0.0	0.069	0.014	0.0	0.0	0.0	0.028	0.0	0.0	0.014	0.139	0.167	0.153	0.0	0.028	0.014	0.014	0.0	0.0
4.4	0.0	0.069	0.014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.042	0.069	0.0	0.0	0.0	0.0	0.0	0.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.028	0.056	0.0	0.0	0.0	0.0	0.0	0.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

DILUTION OF PRECISION PARAMETERS - ACCUMULATIVE GLOBAL DISTRIBUTION

NUMBER	VDOP	HDOP	MDOP	TDOP	PDOP	GDOP
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.8	1.0000	1.0000	1.0000	0.9255	1.0000	1.0000
1.0	1.0000	1.0000	0.6939	0.5826	1.0000	1.0000
1.2	1.0000	0.9771	0.3307	0.3478	1.0000	1.0000
1.4	0.9973	0.4683	0.1174	0.2360	1.0000	1.0000
1.6	0.9254	0.2297	0.0353	0.1584	1.0000	1.0000
1.8	0.7123	0.0794	0.0173	0.1243	1.0000	1.0000
2.0	0.4915	0.0234	0.0039	0.0175	0.9879	1.0000
2.2	0.3299	0.0039	0.0	0.0	0.8051	0.9786
2.4	0.2375	0.0	0.0	0.0	0.5258	0.7897
2.6	0.1865	0.0	0.0	0.0	0.3519	0.5281
2.8	0.1183	0.0	0.0	0.0	0.2430	0.3888
3.0	0.0875	0.0	0.0	0.0	0.1997	0.3005
3.2	0.0641	0.0	0.0	0.0	0.1529	0.2236
3.4	0.0312	0.0	0.0	0.0	0.1043	0.1913
3.6	0.0113	0.0	0.0	0.0	0.0740	0.1697
3.8	0.0030	0.0	0.0	0.0	0.0262	0.1186
4.0	0.0	0.0	0.0	0.0	0.0084	0.0769
4.2	0.0	0.0	0.0	0.0	0.0059	0.0385
4.4	0.0	0.0	0.0	0.0	0.0	0.0086
4.6	0.0	0.0	0.0	0.0	0.0	0.0059
4.8	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	0.0	0.0	0.0	0.0	0.0
5.4	0.0	0.0	0.0	0.0	0.0	0.0
5.6	0.0	0.0	0.0	0.0	0.0	0.0
5.8	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0	0.0	0.0	0.0	0.0	0.0
6.2	0.0	0.0	0.0	0.0	0.0	0.0
6.4	0.0	0.0	0.0	0.0	0.0	0.0
6.6	0.0	0.0	0.0	0.0	0.0	0.0
6.8	0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 (Continued)

NUMBER OF SATELLITES

LAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PROBABILITY (IN PERCENT) OF SEEING EXACTLY N SATELLITES																
90.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.00	0.0	0.0				
85.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93.06	6.94	0.0				
80.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.17	77.78	18.06	0.0				
75.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.33	73.61	16.67	1.39				
70.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.11	72.22	11.11	5.56				
65.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.44	62.50	18.06	0.0				
60.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.56	55.56	13.89	0.0				
55.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.56	63.89	5.56	0.0				
50.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.94	41.67	45.83	5.56	0.0				
45.	0.0	0.0	0.0	0.0	0.0	0.0	11.11	16.67	30.56	38.89	2.78	0.0				
40.	0.0	0.0	0.0	0.0	0.0	0.0	19.44	16.67	29.17	27.78	6.94	0.0				
35.	0.0	0.0	0.0	0.0	0.0	0.0	22.22	18.06	26.39	30.56	1.39	1.39				
30.	0.0	0.0	0.0	0.0	0.0	0.0	26.39	18.06	23.61	30.56	1.39	0.0				
25.	0.0	0.0	0.0	0.0	0.0	0.0	27.78	13.89	26.39	31.94	0.0	0.0				
20.	0.0	0.0	0.0	0.0	0.0	0.0	26.39	15.28	26.39	27.78	4.17	0.0				
15.	0.0	0.0	0.0	0.0	0.0	0.0	19.44	20.83	19.44	36.11	4.17	0.0				
10.	0.0	0.0	0.0	0.0	0.0	0.0	12.50	16.67	40.28	30.56	0.0	0.0				
5.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.83	41.67	31.94	5.56	0.0				
0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.11	50.00	27.78	11.11	0.0				
PROBABILITY (IN PERCENT) OF SEEING N OR MORE SATELLITES																
90.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.0	0.0				
85.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	6.94	0.0				
80.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	95.83	18.06	0.0				
75.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	91.67	18.06	1.39				
70.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	88.89	16.67	5.56				
65.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	80.56	18.06	0.0				
60.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	69.44	13.89	0.0				
55.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	69.44	5.56	0.0				
50.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	93.06	51.39	5.56	0.0				
45.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	88.89	72.22	41.67	2.78	0.0				
40.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	80.56	63.89	34.72	6.94	0.0				
35.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	77.78	59.72	33.33	2.78	1.39				
30.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	73.61	55.56	31.94	1.39	0.0				
25.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	72.22	58.33	31.94	0.0	0.0				
20.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	73.61	58.33	31.94	4.17	0.0				
15.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	80.56	59.72	40.28	4.17	0.0				
10.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	87.50	70.83	30.56	0.0	0.0				
5.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	79.17	37.50	5.56	0.0				
0.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	88.89	38.89	11.11	0.0				
ON A GLOBAL BASIS THE PROBABILITY (IN PERCENT) THAT EXACTLY N SATELLITES WILL BE SEEN																
PROB	0.0	0.0	0.0	0.0	0.0	0.0	12.12	12.95	30.05	38.95	5.64	0.28				
ON A GLOBAL BASIS THE PROBABILITY (IN PERCENT) THAT N OR MORE SATELLITES WILL BE SEEN																
PROB	100.00	100.00	100.00	100.00	100.00	100.00	100.00	87.88	74.93	44.88	5.92	0.28				

Table 7 (Continued)

MAXIMUM AND MINIMUM NUMBERS SEEN AT EACH LATITUDE & LONGITUDE

MAXIMUM

LONGITUDE

LAT	0					50					100					150					200					250					300					350
90.	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
85.	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	9	9	9	9	9	9	9	9	9
80.	10	10	10	10	9	9	9	9	9	9	9	10	10	9	9	10	10	10	10	9	9	9	9	9	10	10	10	9	9	9	9	9	9	9	9	9
75.	10	10	9	9	9	10	10	11	10	9	9	9	9	9	9	9	9	10	10	10	9	9	9	9	9	10	10	10	9	9	9	9	9	9	9	10
70.	11	10	9	9	9	9	10	10	10	9	9	9	9	9	9	9	9	10	11	11	9	9	9	9	9	10	10	10	9	9	9	9	9	9	9	11
65.	9	9	10	9	9	10	10	9	9	9	9	10	9	9	9	9	10	9	9	10	10	9	10	10	10	9	10	9	9	9	9	9	9	9	10	10
60.	9	9	9	9	9	10	10	9	9	9	9	10	9	9	9	9	9	9	9	10	10	10	10	9	8	8	9	9	9	9	9	10	9	9	10	10
55.	9	9	9	9	9	10	9	9	9	9	9	10	10	9	9	9	9	9	9	8	9	9	9	9	9	9	10	9	9	9	9	9	9	9	9	8
50.	10	9	9	9	8	9	9	9	9	9	9	9	9	9	8	8	9	9	9	9	10	9	9	9	8	9	10	9	9	9	8	9	9	9	10	9
45.	9	9	9	9	9	8	9	8	8	7	8	8	9	8	9	9	8	8	9	9	10	9	9	9	9	9	9	9	9	9	9	9	9	9	10	9
40.	8	8	8	9	9	9	10	8	9	9	9	8	10	10	9	8	8	8	9	9	10	9	9	8	9	9	9	9	9	9	8	8	9	9	10	9
35.	8	8	8	9	11	10	8	9	9	9	9	9	9	9	9	9	9	8	9	9	9	9	8	8	8	9	9	9	8	8	8	8	8	9	9	9
30.	8	9	9	9	9	8	9	9	9	9	9	9	8	10	9	9	9	9	8	9	9	9	9	8	8	8	8	8	8	8	8	8	9	9	9	9
25.	9	9	9	9	8	8	8	8	9	9	9	8	8	9	9	9	9	9	9	8	8	9	9	9	8	9	8	9	9	8	8	9	9	9	8	8
20.	8	9	9	9	8	8	8	7	9	9	9	7	8	8	9	9	9	8	8	8	9	9	9	9	10	9	9	9	10	10	8	9	9	9	9	8
15.	9	9	9	9	8	9	9	8	9	9	9	8	8	8	8	9	9	7	9	9	9	9	9	10	9	9	9	8	9	10	9	10	9	9	9	9
10.	8	8	9	8	8	9	9	9	8	9	8	9	9	9	8	9	7	8	8	9	8	8	9	9	9	9	9	8	9	9	9	9	9	8	8	9
5.	10	8	9	8	8	9	9	9	8	9	8	9	9	9	8	9	9	9	9	9	8	9	9	8	9	10	8	8	9	10	9	10	9	8	8	9
0.	10	9	8	8	8	9	9	10	9	8	9	10	9	9	9	8	8	10	10	9	8	8	8	9	9	10	9	8	9	10	9	9	9	8	8	10

MINIMUM

LONGITUDE

LAT	0					50					100					150					200					250					300					350
90.	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
85.	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
80.	9	9	9	9	9	9	9	8	9	9	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
75.	9	9	9	9	9	8	8	9	9	9	8	9	8	8	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
70.	8	8	9	9	8	8	9	9	9	9	9	9	9	6	8	9	9	9	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
65.	8	9	9	9	9	8	9	9	8	8	9	9	9	8	9	9	9	9	8	8	8	9	9	8	8	9	9	9	8	9	8	8	9	9	9	8
60.	8	9	9	8	9	8	9	9	8	8	8	9	9	8	9	8	9	9	9	8	8	9	9	8	8	8	9	8	8	8	8	8	9	9	8	8
55.	8	8	9	8	9	9	9	9	8	8	8	9	9	9	9	8	9	8	6	8	9	9	8	8	8	8	8	9	8	8	8	9	9	9	8	8
50.	8	8	7	8	8	9	8	8	7	8	8	8	9	6	8	8	7	8	8	8	9	7	8	8	8	8	9	9	9	8	8	8	7	8	8	8
45.	8	8	7	6	7	7	8	8	7	6	7	8	9	7	7	6	7	8	8	9	6	6	7	8	8	8	6	8	6	8	8	8	6	7	9	7
40.	8	7	6	6	6	8	8	6	6	6	6	8	8	8	6	6	6	7	8	8	7	6	6	7	8	7	7	6	7	7	8	7	6	7	7	7
35.	8	7	6	6	7	7	7	6	6	6	6	8	8	7	7	6	6	7	8	6	7	7	6	7	8	6	7	6	7	6	8	6	7	6	6	9
30.	8	6	6	7	7	6	7	6	6	6	7	6	7	6	7	7	6	6	7	6	6	7	6	6	8	7	6	6	6	7	8	6	7	6	6	7
25.	9	6	6	7	6	6	8	7	6	7	7	7	8	6	6	7	6	6	8	6	6	6	7	7	8	6	6	6	6	6	8	7	6	6	6	7
20.	7	8	7	6	6	7	8	6	7	7	6	7	8	7	6	6	7	7	8	6	6	6	6	8	8	6	6	6	6	6	8	6	6	6	6	8
15.	8	7	7	6	6	7	8	7	7	7	6	7	8	7	6	6	7	7	8	7	6	6	6	9	7	8	6	6	6	8	7	7	6	6	6	8
10.	8	7	7	7	6	8	8	8	6	6	7	8	9	8	6	7	7	7	8	7	6	6	8	8	8	8	7	6	7	8	8	8	6	6	7	8
5.	8	7	7	8	8	8	8	7	7	7	7	8	9	6	8	8	7	8	8	8	7	8	7	7	7	9	8	7	8	7	8	7	8	7	8	9
0.	7	8	8	8	8	8	7	8	8	7	8	7	9	8	8	8	6	9	7	8	8	8	8	8	7	8	8	7	8	7	9	8	8	8	8	9

Appendix A
NAVSAT SELECTION ALGORITHMS FOR A SATELLITE USER

This appendix describes the algorithms used to select, from all of the navsats in view of a satellite user, those most likely to yield small DOP values. These algorithms were developed to reduce computation costs, accomplished by selecting a value for the input parameter C ($0 < C < 1$), which is the fraction of the area of a sphere with radius equal to the orbital radius of the navsats. If the navsat system orbital configuration involves elliptic orbits, these algorithms cannot be used and C should be set equal to one.* Also, computation costs can be reduced further, with little sacrifice in position determination accuracy, if the zenith/nadir satellite selection mode is used to reduce computation time.

If the navsat orbital configuration involves more than one circular orbit altitude (a "multishell" system) and the satellite user is above all of the shells, the algorithm can be used as presented below. If the satellite user is between or below the shells part of the time, the situation is more complex because there are two possible values for θ_T (see below)--one for the "zenith" navsat on the same side of the earth as the user, and one for the "nadir" navsat on the other side of the earth from the user. In this case, suitable values of C can be obtained by careful consideration of the user/navsat system relative geometries. As with elliptic orbit navsats, C can be set equal to one, and the zenith/nadir navsat selection mode can be used to minimize computation time.

The following is a description of the algorithms for use with any satellite user orbit, as long as the navsat system uses a single altitude, circular orbit. The number of navsats considered for use after the zenith/nadir navsat is selected by C; the larger C is, the larger the number of navsats considered. Values of C from 0.4 to 0.6 generally yield good results.

---

*The algorithms can be used if the satellite user is always above or below all of the navsats and the value of R, which is used in the expression to obtain θ_T, is representative of the navsat orbits. (For example, set R equal to the average of the semimajor axes of the navsat orbits.) This would require a minor modification of the computer program.

The two algorithms derived below, one for the satellite user above the navsats and the other for the satellite user below, use the same criteria for selecting the first navsat of the four to be used for the computation of the DOPs, i.e., the satellite, of those in view of the user, which is closest to the user's zenith or nadir. However, the criteria for selecting the remaining three satellites are not the same for the two algorithms.

SELECTION OF THE FIRST NAVSAT

For convenience of explanation, Fig. A-1 shows the user above the navsats, the spherical surface containing the navsats, and the earth plus 200 n mi of atmosphere (hereafter called earth). Also, the shaded area that is shown will contain the navsats which are retained for the computation of the DOPs, as we will describe later.

At each time point, the angles θ_n and β_n are computed for each user and navsat combination from

$$\theta_n = \cos^{-1}\left(\frac{\overline{R} \cdot \overline{P}}{RP}\right)^*$$

and (A-1)

$$\beta_n = \cos^{-1}\left(\frac{-\overline{U} \cdot \overline{P}}{UP}\right) .$$

If $\theta_n > \phi$, where $\phi = \cos^{-1}\left(\frac{r}{R}\right) + \cos^{-1}\left(\frac{r}{P}\right)$, then the satellite is obscured from the user's view by the earth and is discarded from further consideration until the next step.

If the angle α, which is equal to $\pi - (\theta_n + \beta_n)$, is greater than the navsat antenna beam half-angle, then the user satellite will not be illuminated by the navsat antenna beam and the navsat will not be used in the calculations.

The angle β_1, corresponding to the first satellite not obscured by the earth, and the number of the satellite are stored. Subsequent β's are computed and compared to the β in storage, and the satellite yielding the smallest β is the first of the four navsats used for the computation of DOP values.

---

*$P = |\overline{P}|$ (the length of $\overline{P}$) and $R = |\overline{R}|$ (the length of $\overline{R}$).

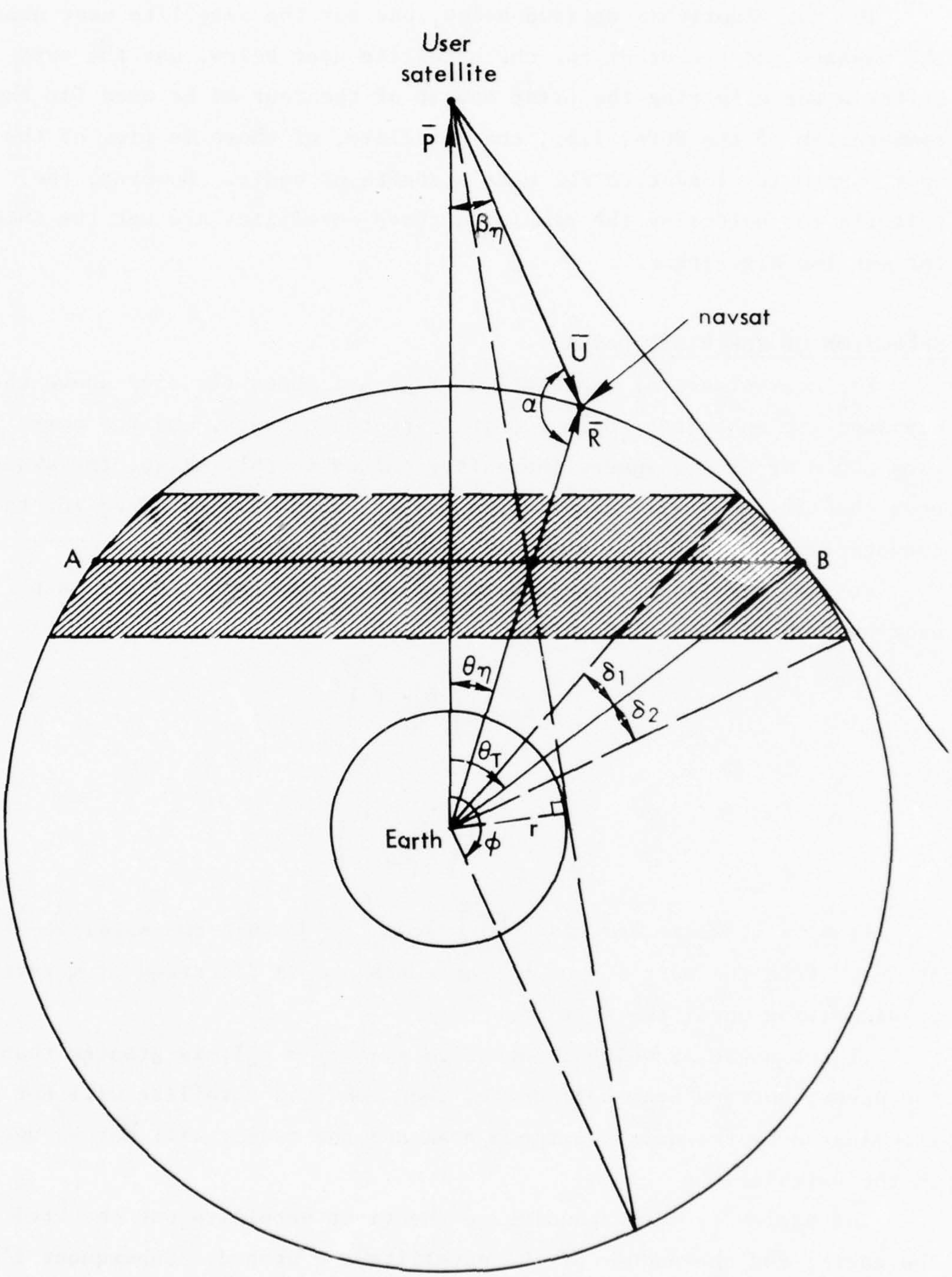


Fig. A-1 — Satellite user above the navsat altitude

For the axis of the navsat antenna pointing toward the center of the earth, it is clear that any navsat above the plane represented by line A-B in Fig. A-1 must have an antenna beam with half-angle greater than 90 deg in order to illuminate the satellite user. If the navsat is below the plane, the antenna beam half-angle required will be less than 90 deg.

SATELLITE USER ABOVE THE NAVSAT SYSTEM

If the remaining three navsats needed for the GDOP computations are on or near the tangent circle A-B (Fig. A-1) and are separated in longitude by 120 deg, then the volume of the tetrahedron formed, as shown in Fig. A-2 (a,b,c,d), will be a near maximum and the corresponding PDOP values will (almost always) be minimum.* The probability that the three satellites will be so arranged is small; thus, all of the satellites in a band (similar to a band between two parallels of latitude) containing the tangent circle, and whose width corresponds to the sum of the central angles δ_1 and δ_2, are retained for the selection of the three remaining satellites. The satellites not in this band are discarded from further consideration until the next time point. The angles δ_1 and δ_2 are obtained from

$$\delta_1 = \sin^{-1}\left(\frac{C}{\sin \theta_T}\right) \quad \text{if } \sin^2 \theta_T > C \,, \tag{A-2}$$

where $\cos \theta_T = |\overline{R}| \,/\, |\overline{P}|$, and $\delta_2 = \delta_1$; or

$$\delta_1 = \theta_T \quad \text{if } \sin^2 \theta_T \leq C \,, \tag{A-3}$$

and

$$\delta_2 = \cos^{-1}\left(1 - 2C\right) - \theta_T \quad .$$

The central angle $\theta_T = \cos^{-1}\left(\frac{R}{P}\right)$ is shown in Fig. A-1. The quantity $0 < C < 1$ (an input quantity) represents the ratio of the area of

*The tangent circle A-B, between a cone with apex at the user's position and the spherical surface containing the navsats, corresponds to the maximum value β_n can have.

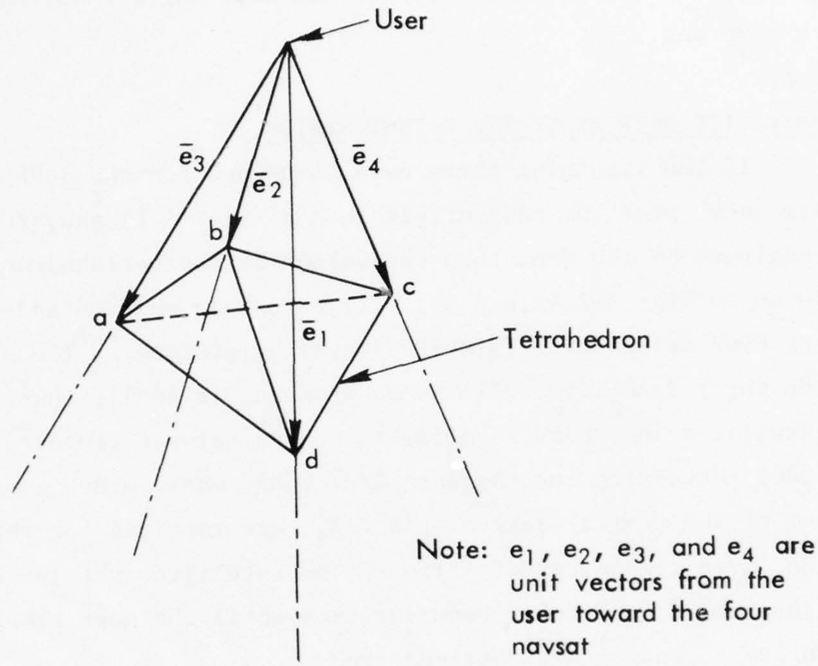


Fig. A-2 — Tetrahedron formed by the ends of unit vectors from a satellite user toward four navsats

the band to the area of the sphere containing the navsats. If the satellites are uniformly distributed, the number of navsats in the band will be the product of C times the total number of navsats. Thus, for $C = 0.25$, the number of GPS satellites in the band (on the average) would be 6. Since the navsats are not usually uniformly distributed, $C \cong 0.5$ should ensure that there will be an adequate number of navsats available.

SATELLITE USER BELOW THE NAVSAT SYSTEM ALTITUDE

The characteristics of the algorithm for satellite selection for a satellite user below the navsats, as shown in Fig. A-3, are not readily apparent if it is desirable to reduce the computational effort that results when all satellites in view are taken four at a time. The number of different combinations of four satellites can be large. For example, a user near the altitude of GPS will, on the average, see 22 of the 24 GPS satellites, and the number of different combinations of four will be 7315.

The satellite selection algorithm presented here and used in the program is based on the simplifying assumptions that the first of the four satellites to be used for computing GDOP values is the one nearest the user's zenith (or nadir) and that the other three satellites are in or near a plane which is normal to the vector $\bar{P}$. The additional program statements required to select the *optimum* orientation of the plane were not used because of singularity problems that could occur when the user is just below the navsat altitude.*

Figure A-3 shows the orbit containing the first of the four navsats chosen for the tetrahedron volume computation and the band, on the spherical surface containing the navsats, which will be used to select the other three navsats.

The angles δ_1 and δ_2 are determined as before, except θ_T is now computed from

$$\theta_T = \rho + \cos^{-1}\left(\frac{|\bar{P}|}{|\bar{R}|} \cos\rho\right),$$

---

*If obtaining minimum GDOP values is essential, it is recommended that the algorithm be ignored and that all possible combinations of four satellites be examined.

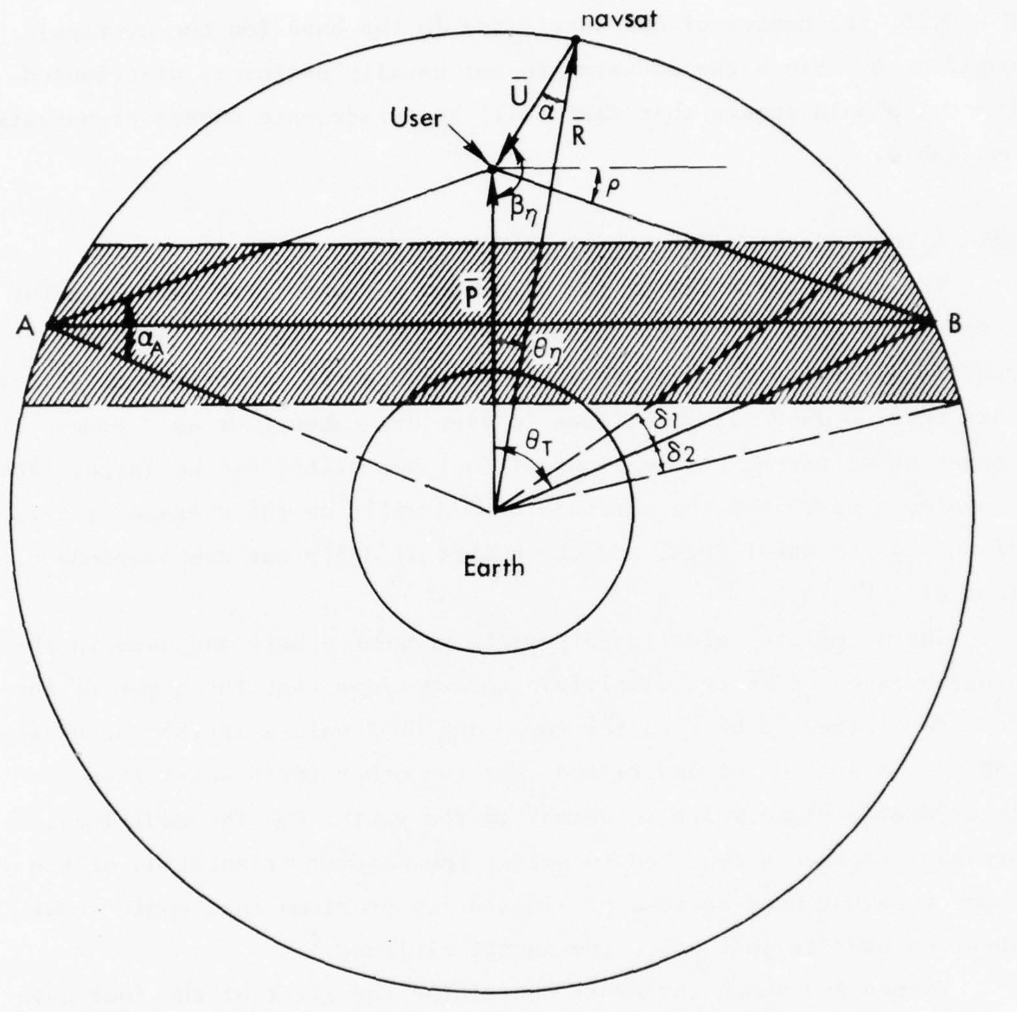


Fig. A-3— Orientation with satellite user below the navsat altitude

where ρ is the angle between the user's horizontal and a line from the user to the circle represented by the line A-B in Fig. A-3. If the first navsat chosen is on the user's vertical, then it can be shown that the optimum value for ρ is about 19.5 deg. This value of ρ will maximize the volume of the tetrahedron formed by joining the tips of the four unit vectors which point from the user to the four navsats. If the first chosen navsat is above the user's horizontal (as shown in the figure), the angle ρ will be below the user's horizontal--and vice versa.

Figure A-3 shows that the half-angle of the navsat antenna beam, which is directed toward the center of the earth, must be as large as the angle α if the user satellite is to receive ranging information from a navsat located at point A.

Appendix B

PROGRAM LISTING

MAIN

```
      COMMON/ORBIS/P(37,25)/CON/C(18)
      DIMENSION AA(3),G(37,4),IOS(37),ISIC(4),KXX(58905,4),NSGD(37),R(3)
     1,RF(3),RMX(37,3),SIGT(6),U(3),UPV(3),USUV(37,3),UTS(3),VE(3),Z(3),
     2 YE(3),XN(3),ISAVE(37),IINT(37),UEL(37),IOUT(37),STN(3)
      DIMENSION QSR(36),CAG(19,18),GLEB(18),PIB(18),ACLAT(19,36),
     1 ACTOT(36),OBLAT(19,36),OBDIS(36),CL(19),MIN(19,36),MAX(19,36),
     2 CAGX(19,18),NSPL(19),SKEG(19,36,6),SKEGX(19,36,6),GLOS(6,36),
     3 CDOP(19,36,6),ISAPP(32),PER(36)
      REAL LAT,LONG,LATDEG,LADG,LAD
      KTR=48
      IPRINT=0
      Z(1)=0.
      Z(2)=0.
      Z(3)=1.E+10
C
C    LOC=1; USER ON SATELLITE
C    LOC=2; USER ON GROUND AT SPECIFIED LATITUDE AND LONGITUDE
C    LOC=3; GLOBAL CALCULATIONS
C
      READ (5,175) LOC,NJL,ISCMP
      GO TO (100,110,120), LOC
C
  100 DO 105 K=1,5
      READ (5,180) (P(N,K),N=1,NJL)
  105 CONTINUE
      READ (5,180) (PER(N),N=1,NJL)
      NJM=NJL+1
      READ (5,180) (P(NJM,K),K=1,5)
      READ (5,185) PER(NJM),AIN,CK
      READ (5,175) INC,ITF
      GO TO 155
C
  110 DO 115 K=1,5
      READ (5,180) (P(N,K),N=1,NJL)
  115 CONTINUE
      READ (5,180) (PER(N),N=1,NJL)
      READ (5,185) ATL,ONGL,ELEVAT
      READ (5,175) INC,ITF
      GO TO 155
C
  120 DO 125 K=1,5
      READ (5,180) (P(N,K),N=1,NJL)
  125 CONTINUE
      READ (5,180) (PER(N),N=1,NJL)
      READ (5,185) LATDEG,ELEVAT
      READ (5,175) LATIC,LONIC,INC,ITF,IPFREQ,ITIME
      DO 135 MA=1,19
      CL(MA)=0.
      NSPL(MA)=0
      DO 130 MB=1,36
      MIN(MA,MB)=30
      MAX(MA,MB)=0
      DO 130 MC=1,6
      SKEGX(MA,MB,MC)=0.
      CDOP(MA,MB,MC)=0.
  130 SKEG(MA,MB,MC)=0.
      DO 135 MD=1,18
      CAGX(MA,MD)=0.
```

MAIN

```
  135 CAG(MA,MD)=0.
      DC 140 MA=1,36
      DO 140 MB=1,6
  140 GLOS(MB,MA)=0.
      DO 150 MA=1,19
      ACTOT(MA)=0.
      OBDIS(MA)=0.
      DO 145 MD=1,36
      ACLAT(MA,MD)=0.
  145 OBLAT(MA,MD)=0.
  150 GLEB(MA)=0.
C
  155 CONTINUE
      WRITE (6,195)
      WRITE (6,190)
      DO 160 IP=1,NJL
      WRITE (6,215) (IP,(P(IP,IV),IV=1,5),PER(IP))
  160 CONTINUE
      IF(LOC.EQ.1) WRITE (6,200)
      IP=NJL+1
      IF(LOC.EQ.1) WRITE (6,215) (IP,(P(IP,IV),IV=1,5),PER(IP))
      IF(LOC.EQ.2) WRITE (6,210) ATL,ONGL,ELEVAT
      IF(LOC.EQ.3) WRITE (6,205) ELEVAT,LATDEG,LATIC,LONIC,ITIME
      ITT=(ITF-1)*INC
      WRITE (6,220) ITT,INC
      IF(LOC.EQ.1) WRITE (6,225) AIN,CK
      IF(LOC.EQ.1.AND.ISCMP.EQ.0) WRITE (6,166)
      IF(LOC.NE.1.AND.ISCMP.EQ.0) WRITE (6,165)
      IF(ISCMP.EQ.1) WRITE (6,170)
C
C  THE FOLLOWING FORMATS HAVE TO DO WITH INPUT
C
  165 FORMAT(1H0,10X,'THE SATELLITE MOST NEARLY OVERHEAD IS USED AS ONE
     1OF THE FOUR'/,11X,'IN ALL CALCULATIONS OF THE VOLUME OF THE TETRAH
     2EDRON')
  166 FORMAT(1H0,10X,'THE SATELLITE MOST NEARLY ABOVE OR BELOW IS USED A
     1S ONE OF THE FOUR'/,11X,'IN ALL CALCULATIONS OF THE VOLUME OF THE
     2TETRAHEDRON')
  170 FORMAT(1H0,10X,'ALL SATELLITES, TAKEN FOUR AT A TIME, ARE USED IN'
     1,/,11X,'THE CALCULATIONS OF THE VOLUME OF THE TETRAHEDRON')
  175 FORMAT(10I5)
  180 FORMAT(12F6.0)
  185 FORMAT(7F10.0)
  190 FORMAT(1H0,22X,' ECC',5X,'ARGP',4X,'RASC',4X,'INC',5X,'ANOM',4X,
     1'PER',//)
  195 FORMAT(1H1,//32X,'ORBITAL ELEMENTS')
  200 FORMAT(1H0,10X,'USER SATELLITE ORBITAL ELEMENTS'/)
  205 FORMAT(1H0,10X,'GLOBAL DISTRIBUTION CALCULATIONS',//,
     1 11X,'MASKING ANGLE = ',F6.2,' DEGREES',/,
     2 11X,'LATITUDE STEP = ',F6.2,' DEGREES',/,
     3 11X,'LATITUDE INCREMENT = ',I3,/,
     4 11X,'LONGITUDE INCREMENT = ',I3,/,
     5 11X,'DILUTION OF PRECISION PARAMETERS PRINTED AT TIME INCREMENT O
     6F ',I5)
  210 FORMAT(1H0,10X,'USER LOCATION ON EARTH',/11X,
     1       'LATITUDE = ',F5.2,' DEGREES'/,11X,'LONGITUDE = ',F5.2,
     2       ' DEGREES',/, 11X,'MASKING ANGLE = ',F6.2,' DEGREES')
  215 FORMAT(1H ,15X,I3,1X,6F8.2)
```

MAIN

```
  220 FORMAT(1H0,10X,'TOTAL TIME(MIN) = ',I5,/,11X,
     1    'TIME INCREMENT(MIN) = ',I3)
  225 FORMAT(1H ,10X,'BEAMWIDTH ANGLE(DEG) = ',F6.2,/,11X,
     1  'FRACTION OF NAVSAT SPHERICAL AREA = ',F6.3)
C
C   SET UP ORBITAL ELEMENTS
C
      DO 230 N=1,NJL
      P(N,22)=22808.*(PER(N)/24.)**(2./3.)
      CALL ORBINI (N)
  230 CONTINUE
      IF(LOC.EQ.2.OR.LOC.EQ.3) GO TO 235
      P(IP,22)=22808.*(PER(IP)/24.)**(2./3.)
      CALL ORBINI (IP)
  235 CONTINUE
      INCA=0
      NSTO=0
      MAXNSS=0
      DO 625 IT=1,ITF
      TID=FLOAT(INCA)/1440.
      INCA=INCA+INC
      NN=IP
      IF(LOC.EQ.2.OR.LOC.EQ.3) NN=NJL
      DO 240 N=1,NN
      CALL ORBIT (N,TID,PER,RF,VE,AA)
      DO 240 IV=1,3
      RMX(N,IV)=RF(IV)
  240 CONTINUE
      IF(LOC.EQ.2) GO TO 335
      IF(LOC.EQ.3) GO TO 330
C
C
      DO 245 IV=1,3
      UPV(IV)=RMX(IP,IV)
  245 CONTINUE
      IK=0
      BETAMN=4.000000
      DO 265 N=1,NJL
      DO 250 IV=1,3
      R(IV)=RMX(N,IV)
  250 CONTINUE
      CALL VECTOR (R,2,UPV,UTS)
      AR=SQRT(DOT(R,R))
      AP=SQRT(DOT(UPV,UPV))
      A=ARCOS(2.0926144E+07/AR)
      IF(AP.LE.2.0926144E+07) WRITE(6,251)
  251 FORMAT(1H ,/,3X,'TERMINATION OF RUN, ALTITUDE APPROCHING ZERO')
      IF(AP.LE.2.0926144E+07) STOP
      B=ARCOS(2.0926144E+07/AP)
      PHI=A+B
      DOTRP=DOT(R,UPV)
      THETN=ARCOS(DOTRP/(AR*AP))
      IF(THETN.GE.PHI) GO TO 265
      IK=IK+1
      ISAVE(IK)=N
      AU=SQRT(DOT(UTS,UTS))
      DOTUP=DOT(UTS,UPV)
      BETAN=ARCOS(-DOTUP/(AU*AP))
```

MAIN

```
      AIWID=AIN/C(2)
      BWIDTH=C(3)-(THETN+BETAN)
      IF(AIWID.LT.BWIDTH) GO TO 265
      BETASV=BETAN
      IF(BETAN.GT.C(5)) BETAN=C(3)-BETAN
  255 IF(BETAN.LT.BETAMN) GO TO 260
      GO TO 265
  260 ISATNO=N
      BETAMN=BETAN
      BETAS=BETASV
  265 CONTINUE
      DO 285 I=1,IK
      IF(ISAVE(I).EQ.ISATNO) GO TO 270
      GO TO 285
  270 INDX=I
      DO 275 KI=1,INDX
      KII=KI+1
      IINT(KII)=ISAVE(KI)
  275 CONTINUE
      INDX=INDX+1
      DO 280 KI=INDX,IK
      IINT(KI)=ISAVE(KI)
  280 CONTINUE
      GO TO 290
  285 CONTINUE
  290 IINT(1)=ISATNO
      IF(ISCMP.EQ.1) GO TO 335
C
C  THE NUMBERS OF THE SATELLITES WHICH FIT CRITERIA FOR USE, PLUS THE
C  ONE NEAREST TO OVERHEAD HAVE BEEN CALCULATED
C
      IOS(1)=IINT(1)
      NSS=1
      DO 295 IV=1,3
      R(IV)=RMX(IINT(1),IV)
  295 CONTINUE
      CALL VECTOR (R,2,UPV,UTS)
      CALL UNIVEC (UTS,U)
      DO 300 IV=1,3
      USUV(IINT(1),IV)=U(IV)
  300 CONTINUE
      DO 325 N=2,IK
      DO 305 IV=1,3
      R(IV)=RMX(IINT(N),IV)
  305 CONTINUE
      CALL VECTOR (R,2,UPV,UTS)
      CALL UNIVEC (UTS,U)
      DO 310 IV=1,3
      USUV(IINT(N),IV)=U(IV)
  310 CONTINUE
      AR=SQRT(DOT(R,R))
      AP=SQRT(DOT(UPV,UPV))
      IF(AP.GT.AR) THETT=ARCOS(AR/AP)
      IF(AP.LE.AR.AND.BETAS.GT.C(5)) THETT=109.5/C(2)-ARSIN(AP*.33380686
     1/AR)
      IF(AP.LE.AR.AND.BETAS.LE.C(5)) THETT=70.5/C(2)-ARSIN(AP*.33380686/
     1AR)
      DOTRP=DOT(R,UPV)
```

```
      THETN=ARCOS(DOTRP/(AR*AP))
      SINTT=SIN(THETT)
      SINTSQ=SINTT**2
      IF(SINTSQ.GT.CK) GO TO 315
      DELONE=THETT
      ANG=1.-(CK/.5)
      DELTWO=ARCOS(ANG)-THETT
      GO TU 320
  315 CONTINUE
      DELONE=ARSIN(CK/SINTT)
      DELTWO=DELONE
  320 IF(THETN.LT.(THETT-DELONE)) GO TO 325
      IF(THETN.GT.(THETT+DELTWO)) GO TO 325
      NSS=NSS+1
      IOS(NSS)=IINT(N)
  325 CONTINUE
      IF(NSS.LE.4) GO TO 625
      GO TO 335
C
C END OF USER ON SATELLITE
C
C CALCULATIONS FOR USER ON EARTH AT SPECIFIED LAT AND LONG, AND GLOBAL
C DISTRIBUTIONS FOLLOW
  330 CONTINUE
      LKL=36
      LLL=19
  335 CONTINUE
      IF(LOC.EQ.2.OR.LOC.EQ.1) LKL=1
      IF(LOC.EQ.2.OR.LOC.EQ.1) LLL=1
      DO 500 K=1,LKL,LONIC
      DO 500 L=1,LLL,LATIC
      IF(LOC.EQ.1.AND.ISCMP.EQ.0) GO TO 400
      IF(LOC.EQ.1.AND.ISCMP.EQ.1) GO TO 375
      LONG=FLOAT(K-1)*10.
      LAT=90.-FLOAT(L-1)*LATDEG
      IF(LOC.EQ.2) LONG=ONGL
      IF(LOC.EQ.2) LAT=ATL
      CALL POINT (LONG,LAT,TID,UPV)
      NSS=0
      CL(L)=CL(L)+1.
      DO 350 N=1,NJL
      DO 340 IV=1,3
      R(IV)=RMX(N,IV)
  340 CONTINUE
      CALL VECTOR (UPV,2,R,STN)
      SE=-DOT(STN,UPV)/SQRT(DOT(STN,STN)*DOT(UPV,UPV))
      IF(ABS(SE).GE..9999999) SE=SIGN(1.,SE)
      EL=ARSIN(SE)*C(2)
      IF(EL.LT.ELEVAT) GO TO 350
      NSS=NSS+1
      IINT(NSS)=N
      UEL(N)=EL
      CALL VECTOR (R,2,UPV,UTS)
      CALL UNIVEC (UTS,U)
      DO 345 IV=1,3
      USUV(N,IV)=U(IV)
  345 CONTINUE
  350 CONTINUE
```

MAIN

```
      IF(NSS.GE.4) GO TO 355
      IF(NSS.LT.4) GO TO 500
  355 CONTINUE
      NSTO=NSTO+NSS
      NSPL(L)=NSPL(L)+NSS
      NSP=NSS+1
      MAXNSS=MAX0(MAXNSS,NSS)
      HIGH=0.
      DO 365 NUM=1,NSS
      IX=IINT(NUM)
      AEA=UEL(IX)
      IF(AEA.GT.HIGH) GO TO 360
      IF(AEA.LE.HIGH) GO TO 365
  360 HIGH=AEA
      NN=NUM
  365 CONTINUE
      DO 370 NU=1,NSS
      IF(NU.EQ.NN) NX=1
      IF(NU.LT.NN) NX=NU+1
      IF(NU.GT.NN) NX=NU
      IOS(NX)=IINT(NU)
  370 CONTINUE
      GO TO 400
C
C IOS(NSS) HAS THE SATELLITE NEAREST TO OVERHEAD, THEN ALL OTHERS
C WHICH FIT CRITERIA
C
C NEXT CALCULATIONS ARE CONCERNED WITH FINDING THE COMBINATION OF
C FOUR SATELLITES WHICH HAVE THE GREATEST VALUE OF THE VOLUME OF THE
C TETRAHEDRON FORMED BY THEM
C
  375 CONTINUE
      DO 390 IKN=1,IK
      DO 380 IV=1,3
      R(IV)=RMX(IINT(IKN),IV)
  380 CONTINUE
      CALL VECTOR (R,2,UPV,UTS)
      CALL UNIVEC (UTS,U)
      DO 385 IV=1,3
      USUV(IINT(IKN),IV)=U(IV)
  385 CONTINUE
  390 CONTINUE
      DO 395 IJK=1,IK
  395 IOS(IJK)=IINT(IJK)
  400 BOX=-10.
      IF(ISCMP.EQ.1) GO TO 405
      KOT=NSS
      NSS=NSS-1
      CALL TAAT (NSS,KCOM,KXX)
      ISIC(1)=IOS(1)
      LPN=2
      GO TO 410
  405 KOT=IK
      IF (LOC.EQ.2.OR.LOC.EQ.3) KOT=NSS
      CALL TALL (KOT,KCOM,KXX)
      LPN=1
  410 DO 430 M=1,KCOM
```

```
      DO 415 LPQ=LPN,4
      NUX=KXX(M,LPQ)
      ISIC(LPQ)=IOS(NUX)
  415 CONTINUE
      CALL VOLUME (USUV,ISIC,VOLUM)
      IF(VOLUM.GT.BOX) GO TO 420
      IF(VOLUM.LE.BOX) GO TO 430
  420 BOX=VOLUM
      DO 425 MC=1,4
      NSGD(MC)=ISIC(MC)
  425 CONTINUE
  430 CONTINUE
      DO 440 N=1,4
      DO 435 IV=1,3
      R(IV)=RMX(NSGD(N),IV)
  435 CONTINUE
      CALL VECTOR (R,2,UPV,UTS)
      CALL VECTOR (Z,3,UPV,YE)
      CALL VECTOR (UPV,3,YE,XN)
      AX=SQRT(DOT(XN,XN))
      AY=SQRT(DOT(YE,YE))
      AP=SQRT(DOT(UPV,UPV))
      ALT=AP/6076.116-3444.
      AS=SQRT(DOT(UTS,UTS))
      G(NSGD(N),1)=DOT(XN,UTS)/(AX*AS)
      G(NSGD(N),2)=DOT(YE,UTS)/(AY*AS)
      G(NSGD(N),3)=DOT(UPV,UTS)/(AP*AS)
      G(NSGD(N),4)=1.
  440 CONTINUE
      CALL COVNAV (G,NSGD,4,SIGT)
      IF(LOC.EQ.3) GO TO 480
      IF(LOC.EQ.2) ALT=0.
      DO 445 II=1,4
      IOUT(II)=NSGD(II)
  445 CONTINUE
      IL=1
      LK=4
      DO 455 NN=1,KOT
      ITST=NSGD(IL)
      IF(ITST.EQ.IOS(NN)) GO TO 450
      LK=LK+1
      IOUT(LK)=IOS(NN)
      GO TO 455
  450 IL=IL+1
      IF(IL.EQ.5) GO TO 460
  455 CONTINUE
  460 KOS=NN+1
      DO 465 LK=KOS,KOT
      IOUT(LK)=IOS(LK)
  465 CONTINUE
      ITOUT=(IT-1)*INC
      KTR=KTR+2
      IF(KOT.GT.18) KTR=KTR+1
      IF(KTR.GE.50) GO TO 470
      GO TO 475
  470 WRITE (6,525)
      KTR=0
  475 WRITE (6,530) ITOUT,ALT,(SIGT(KP),KP=1,6),(IOUT(KP),KP=1,KOT)
```

```
C
C END OF CALCULATION FOR SINGLE USER ON EARTH
C
      GO TO 625
C
C FOLLOWING CALCULATIONS FOR GLOBAL DISTRIBUTION
C
  480 DO 485 IDOP=1,6
  485 CDOP(L,K,IDOP)=SIGT(IDOP)
      DO 490 NS=1,6
      KA=MAX0(1,MIN0(INT(SIGT(NS)*5.+1.),36))
  490 SKEG(L,KA,NS)=SKEG(L,KA,NS)+1.
      DO 495 NA=1,KOT
      I=IOS(NA)
      ELT=UEL(I)
      KO=MIN0(INT(ELT/5.)+1,18)
  495 CAG(L,KO)=CAG(L,KO)+1.
      MAX(L,K)=MAX0(MAX(L,K),KOT)
      MIN(L,K)=MIN0(MIN(L,K),KOT)
      OBLAT(L,NSP)=OBLAT(L,NSP)+1.
  500 CONTINUE
      IF(LOC.EQ.3.AND.IPFREQ.EQ.0) GO TO 625
C                                            NO INTERMEDIATE PRINT
      IF(IPRINT.EQ.0.AND.IT.EQ.1) GO TO 505
C                                            PRINT FIRST TIME STEP
      IPRINT=IPRINT+1
      IF(IPRINT.EQ.ITIME) GO TO 505
C                                            PRINT EACH TIME STEP REQUESTED
      GO TO 625
  505 IPRINT=0
      DO 515 IDOP=1,6
      IF(IDOP.EQ.1) WRITE (6,535) ITIME
      IF(IDOP.EQ.2) WRITE (6,540) ITIME
      IF(IDOP.EQ.3) WRITE (6,545) ITIME
      IF(IDOP.EQ.4) WRITE (6,550) ITIME
      IF(IDOP.EQ.5) WRITE (6,555) ITIME
      IF(IDOP.EQ.6) WRITE (6,560) ITIME
      IF(LATDEG.EQ.10.) WRITE (6,565)
      IF(LATDEG.EQ.5.) WRITE (6,570)
      ICT=-10
      DO 510 IC=1,36
      ICT=ICT+10
      IF(ICT.LE.90.OR.ICT.GE.190) WRITE (6,575) ICT,(CDOP(IK,IC,IDOP),IK
     1=1,19)
      IF(ICT.EQ.100) WRITE (6,580) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.110) WRITE (6,585) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.120) WRITE (6,590) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.130) WRITE (6,595) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.140) WRITE (6,600) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.150) WRITE (6,605) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.160) WRITE (6,610) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.170) WRITE (6,615) (CDOP(IK,IC,IDOP),IK=1,19)
      IF(ICT.EQ.180) WRITE (6,620) (CDOP(IK,IC,IDOP),IK=1,19)
  510 CONTINUE
  515 CONTINUE
      DO 520 ICL=1,19
      DO 520 ICK=1,36
      DO 520 ICD=1,6
```

MAIN

```
  520 CDOP(ICL,ICK,ICD)=0.
C
C  THE FOLLOWING FORMATS HAVE TO DO WITH A SPECIFIED TIME STEP REQUEST
C  FOR PRINTING
C
  525 FORMAT(1H1,/,1X,'TIME(MN)',1X,'ALT(NM)',4X,'VDOP',
     1 5X,'HDOP',5X,'MDOP',5X,'TDOP',5X,'PDOP',5X,'GDOP',4X,
     2      'SATELLITES CHOSEN',//)
  530 FORMAT(1H0,I7,F9.0,6(F9.3),1X,18(1X,I2),/,72X,18(1X,I2))
  535 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'VDOP - ALTITUDE')
  540 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'HDOP - POSITION ERROR IN HORIZ
     1ONTAL PLANE')
  545 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'MDOP - LARGER COMPONENT OF POS
     1ITION ERROR')
  550 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'TDOP - TIME')
  555 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'PDOP - THREE DIMENSIONAL POSIT
     1ION ERROR')
  560 FORMAT(1H1,//,10X,'TIME = ',I6,20X,'GDOP - FOUR DIMENSIONAL POSITI
     1ON ERROR')
  565 FORMAT(1H0,52X,'LATITUDE',//,9X,' 90',3X,' 80',3X,' 70',3X,' 60',
     1  3X,' 50',3X,' 40',3X,' 30',3X,' 20',3X,' 10',3X,'  0',3X,'-10',
     2  3X,'-20',3X,'-30',3X,'-40',3X,'-50',3X,'-60',3X,'-70',3X,'-80',
     3  3X,'-90',/)
  570 FORMAT(1H0,52X,'LATITUDE',//,9X,' 90',3X,' 85',3X,' 80',3X,' 75',
     1  3X,' 70',3X,' 65',3X,' 60',3X,' 55',3X,' 50',3X,' 45',3X,' 40',
     2  3X,' 35',3X,' 30',3X,' 25',3X,' 20',3X,' 15',3X,' 10',3X,'  5',
     3  3X,'  0',/)
  575 FORMAT(1H ,2X,I3,1X,19F6.2)
  580 FORMAT(1H ,'L',1X,'100',1X,19F6.2)
  585 FORMAT(1H ,'O',1X,'110',1X,19F6.2)
  590 FORMAT(1H ,'N',1X,'120',1X,19F6.2)
  595 FORMAT(1H ,'G',1X,'130',1X,19F6.2)
  600 FORMAT(1H ,'I',1X,'140',1X,19F6.2)
  605 FORMAT(1H ,'T',1X,'150',1X,19F6.2)
  610 FORMAT(1H ,'U',1X,'160',1X,19F6.2)
  615 FORMAT(1H ,'D',1X,'170',1X,19F6.2)
  620 FORMAT(1H ,'E',1X,'180',1X,19F6.2)
C
  625 CONTINUE
      IF(LOC.EQ.1.OR.LOC.EQ.2) GO TO 920
      MNSSPO=MAXNSS+1
      DO 630 LI=1,36
  630 QSR(LI)=FLOAT(LI-1)*.2
      DO 640 IX=1,18
      PIB(IX)=0.
      DO 635 IY=1,19
  635 PIB(IX)=PIB(IX)+CAG(IY,IX)
  640 PIB(IX)=(PIB(IX)/FLOAT(NSTO))*100.
      DO 660 LA=1,19
      IF(CL(LA).EQ.0..OR.NSPL(LA).EQ.0) GO TO 660
      DO 650 N=1,36
      DO 650 I=1,6
      SKEGX(LA,N,I)=0.
      DO 645 J=N,36
  645 SKEGX(LA,N,I)=SKEGX(LA,N,I)+SKEG(LA,J,I)
  650 SKEGX(LA,N,I)=SKEGX(LA,N,I)/CL(LA)
      DO 660 LC=1,18
      CAGX(LA,LC)=0.
```

```
      DO 655 LF=LC,18
  655 CAGX(LA,LC)=CAGX(LA,LC)+CAG(LA,LF)
      CAGX(LA,LC)=CAGX(LA,LC)/FLOAT(NSPL(LA))
  660 CONTINUE
      WRITE (6,780)
      WRITE (6,785) (PIB(IX),IX=1,18)
      IF(LATDEG.EQ.5.) WRITE (6,795)
      IF(LATDEG.EQ.10.) WRITE (6,800)
      ICT=-5
      DO 665 LC=1,18
      ICT=ICT+5
      WRITE (6,815) ICT,(CAGX(LA,LC),LA=1,19)
  665 CONTINUE
      CVS=0.
      DO 680 LM=1,19
      IF(CL(LM).EQ.0..OR.NSPL(LM).EQ.0) GO TO 680
      CV=COS((90.-FLOAT(LM-1)*LATDEG)*C(1))
      CVS=CVS+CV
      DO 670 IN=1,6
      DO 670 II=1,36
  670 GLOS(IN,II)=GLOS(IN,II)+SKEGX(LM,II,IN)*CV
      DO 675 LN=1,18
  675 GLEB(LN)=GLEB(LN)+CAGX(LM,LN)*CV
  680 CONTINUE
      DO 685 LN=1.18
  685 GLEB(LN)=GLEB(LN)/CVS
      WRITE (6,805)
      WRITE (6,810) (GLEB(IC),IC=1,18)
      DO 690 IN=1,6
      DO 690 II=1,36
  690 GLOS(IN,II)=GLOS(IN,II)/CVS
      DO 695 JDOP=1,6
      IF(JDOP.EQ.1) WRITE (6,830)
      IF(JDOP.EQ.2) WRITE (6,835)
      IF(JDOP.EQ.3) WRITE (6,840)
      IF(JDOP.EQ.4) WRITE (6,845)
      IF(JDOP.EQ.5) WRITE (6,850)
      IF(JDOP.EQ.6) WRITE (6,855)
      IF(LATDEG.EQ.10.) WRITE (6,820)
      IF(LATDEG.EQ.5.) WRITE (6,825)
      DO 695 IQSR=1,36
      WRITE (6,775) QSR(IQSR),(SKEGX(LK,IQSR,JDOP),LK=1,19)
  695 CONTINUE
      WRITE (6,860)
      DO 700 IQSR=1,36
      WRITE (6,865) QSR(IQSR),(GLOS(IN,IQSR),IN=1,6)
  700 CONTINUE
      WRITE (6,870)
      LADG=90.
      IF(LATDEG.EQ.10.) LAD=-10.
      IF(LATDEG.EQ.5.) LAD=-5.
      WRITE (6,880)
      DO 705 IL=1,19
      WRITE (6,885) LADG,(MAX(IL,IK),IK=1,36)
      LADG=LADG+LAD
  705 CONTINUE
      WRITE (6,875)
      LADG=90.
```

MAIN

```
      DO 715 IL=1,19
      DO 710 IX=1,36
      IF(MIN(IL,IX).EQ.30) MIN(IL,IX)=0
  710 CONTINUE
      WRITE (6,885) LADG,(MIN(IL,IK),IK=1,36)
      LADG=LADG+LAD
  715 CONTINUE
      DO 720 N=1,MNSSPO
      OBDIS(N)=0.
      DO 720 L=1,19
      IF(CL(L).EQ.0..OR.NSPL(L).EQ.0) GO TO 720
      OBLAT(L,N)=(OBLAT(L,N)/CL(L))*100.
  720 CONTINUE
      DO 730 L=1,19
      DO 730 N=1,MNSSPO
      ACLAT(L,N)=0.
      DO 725 M=N,MNSSPO
  725 ACLAT(L,N)=ACLAT(L,N)+OBLAT(L,M)
  730 CONTINUE
      CO=0.
      DO 740 L=1,19
      IF(CL(L).EQ.0..OR.NSPL(L).EQ.0) GO TO 740
      CA=COS((90.-FLOAT(L-1)*LATDEG)*C(1))
      CO=CO+CA
      DO 735 N=1,MNSSPO
  735 OBDIS(N)=OBDIS(N)+OBLAT(L,N)*CA
  740 CONTINUE
      DO 745 N=1,MNSSPO
  745 OBDIS(N)=OBDIS(N)/CO
      DO 750 N=1,MNSSPO
      ACTOT(N)=0.
      DO 750 M=N,MNSSPO
  750 ACTOT(N)=ACTOT(N)+OBDIS(M)
      DO 755 I=1,32
      ISAPP(I)=I-1
  755 CONTINUE
      NP=1
      MNS=MNSSPO
      IF (MNSSPO.GT.16) MNS=16
      WRITE (6,890) (ISAPP(I),I=1,16)
  760 WRITE (6,900)
      LADG=90.
      DO 765 IL=1,19
      WRITE (6,895) LADG,(OBLAT(IL,N),N=NP,MNS)
      LADG=LADG+LAD
  765 CONTINUE
      WRITE (6,905)
      LADG=90.
      DO 770 IL=1,19
      WRITE (6,895) LADG,(ACLAT(IL,N),N=NP,MNS)
      LADG=LADG+LAD
  770 CONTINUE
      WRITE (6,910)
      WRITE (6,790) (OBDIS(N),N=NP,MNS)
      WRITE (6,915)
      WRITE (6,790) (ACTOT(N),N=NP,MNS)
      IF(MNSSPO.LT.16) GO TO 920
      IF(MNS.GT.16) GO TO 920
```

MAIN

```
      MNS=MNSSPO
      NP=17
      WRITE (6,890) (ISAPP(I),I=17,32)
      GO TO 760
C
C   THE FOLLOWING FORMATS HAVE TO DO WITH A GLOBAL SYSTEM
C
  775 FORMAT(1H ,F4.1,3X,19F6.3)
  780 FORMAT(1H1,/////1X,'ELEVATION DISTRIBUTION - PROBABILITY THAT THE
     1SATELLITE IN VIEW WILL HAVE ELEVATION ANGLES AS LISTED',//,48X,
     2  'ELEVATION ANGLE')
  785 FORMAT(1H0,6X,'    0-5  5-10 10-15 15-20 20-25 25-30 30-35 35-40 40
     1-45 45-50 50-55 55-60 60-65 65-70 70-75 75-80 80-85 85-90',//,2X,
     2 'PROB',1X,18F6.1)
  790 FORMAT(1H0,3X,'PROB',5X,16F7.2)
  795 FORMAT(1H0,////,1X,'LATITUDE ELEVATION DISTRIBUTION',/,
     1      1X,'PROBABILITY THAT ANY SATELLITE IN VIEW WILL HAVE AN ELEVAT
     2ION ANGLE GREATER THAN OR EQUAL TO THOSE LISTED',//,52X,
     3'LATITUDE',/,2X,'ELEV',/,1X,'ANGLE',  1X,'      90      85      80      75
     4      70      65      60      55      50      45      40      35      30      25      20
     5      15      10       5       0',/)
  800 FORMAT(1H0,////,1X,'LATITUDE ELEVATION DISTRIBUTION',/,
     1      1X,'PROBABILITY THAT ANY SATELLITE IN VIEW WILL HAVE AN ELEVAT
     2ION ANGLE GREATER THAN OR EQUAL TO THOSE LISTED',//,52X,
     3'LATITUDE',/,2X,'ELEV',/,1X,'ANGLE',  1X,'      90      80      70      60
     4      50      40      30      20      10       0     -10     -20     -30     -40     -50
     5   - 60     -70     -80     -90',/)
  805 FORMAT(1H0,////,1X,'ACCUMULATIVE ELEVATION DISTRIBUTION',/,
     11X,'PROBABILITY THAT THE ELEVATION ANGLE IS GREATER THAN OR EQUAL
     2TO THOSE LISTED',//,48X,'ELEVATION ANGLE')
  810 FORMAT(1H0,7X,'     0       5      10      15      20      25      30      35      4
     10      45      50      55      60      65      70      75      80      85',//,2X,
     2 'PROB',1X,18F6.1)
  815 FORMAT(1H ,I3,4X,19F6.2)
  820 FORMAT(1H0,52X,'LATITUDE',//,2X,'NUM',5X,
     1                               ' 90',3X,' 80',3X,' 70',3X,' 60',
     2  3X,' 50',3X,' 40',3X,' 30',3X,' 20',3X,' 10',3X,'  0',3X,'-10',
     3  3X,'-20',3X,'-30',3X,'-40',3X,'-50',3X,'-60',3X,'-70',3X,'-80',
     4  3X,'-90',/)
  825 FORMAT(1H0,52X,'LATITUDE',//,2X,'NUM',5X,
     1                               ' 90',3X,' 85',3X,' 80',3X,' 75',
     2  3X,' 70',3X,' 65',3X,' 60',3X,' 55',3X,' 50',3X,' 45',3X,' 40',
     3  3X,' 35',3X,' 30',3X,' 25',3X,' 20',3X,' 15',3X,' 10',3X,'  5',
     4  3X,'  0',/)
  830 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
     1ISTRIBUTION',/,1X,'PROBABILITY THAT ALTITUDE DOP WILL BE GREATER T
     2HAN NUMBER LISTED',//)
  835 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
     1ISTRIBUTION',/,1X,'PROBABILITY THAT POSITION DOP IN HORIZONTAL PLA
     2NE WILL BE GREATER THAN NUMBER LISTED',//)
  840 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
     1ISTRIBUTION',/,1X,'PROBABILITY THAT LARGER COMPONENT OF POSITION D
     2OP WILL BE GREATER THAN NUMBER LISTED',//)
  845 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
     1ISTRIBUTION',/,1X,'PROBABILITY THAT TIME DOP WILL BE GREATER THAN
     2NUMBER LISTED',//)
  850 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
     1ISTRIBUTION',/,1X,'PROBABILITY THAT THREE DIMENSIONAL POSITION DOP
```

MAIN

```
   2 WILL BE GREATER THAN NUMBER LISTED',//)
855 FORMAT(1H1,///,1X,'DILUTION OF PRECISION - ACCUMULATIVE LATITUDE D
   1ISTRIBUTION',/,1X,'PROBABILITY THAT FOUR DIMENSIONAL POSITION DOP
   2WILL BE GREATER THAN NUMBER LISTED',//)
860 FORMAT(1H1,///,1X,'DILUTION OF PRECISION PARAMETERS - ACCUMULATIVE
   1 GLOBAL DISTRIBUTION',//,8X,'NUMBER',7X,'VDOP',6X,'HDOP',6X,
   2  'MDOP',6X,'TDOP',6X,'PDOP',6X,'GDOP',/)
865 FORMAT(1H ,9X,F3.1,3X,6F10.4)
870 FORMAT(1H1,1X,' MAXIMUM AND MINIMUM NUMBERS SEEN AT EACH LATITUDE
   1& LONGITUDE')
875 FORMAT(1H0,/,38X,'MINIMUM',//,37X,'LONGITUDE',//,
   1 32X,2('1',9X),2('2',9X),2('3',9X),/,22X,3('5',9X,'0',9X),
   2 '5',/,5X,'LAT',4X,8('0',9X),/)
880 FORMAT(1H0,/,38X,'MAXIMUM',//,37X,'LONGITUDE',//,
   1 32X,2('1',9X),2('2',9X),2('3',9X),/,22X,3('5',9X,'0',9X),
   2 '5',/,5X,'LAT',4X,8('0',9X),/)
885 FORMAT(1H ,3X,F4.0,3X,36I2)
890 FORMAT(1H1,40X,'NUMBER OF SATELLITES',//,5X,'LAT',3X,16I7)
895 FORMAT(1H ,3X,F4.0,5X,16F7.2)
900 FORMAT(1H0,/,10X,'PROBABILITY (IN PERCENT) OF SEEING EXACTLY N SAT
   1ELLITES',/)
905 FORMAT(1H0,/,10X,'PROBABILITY (IN PERCENT) OF SEEING N OR MORE SAT
   1ELLITES',/)
910 FORMAT(1H0,/,1X,'ON A GLOBAL BASIS THE PROBABILITY (IN PERCENT) TH
   1AT EXACTLY N SATELLITES WILL BE SEEN')
915 FORMAT(1H0,/,1X,'ON A GLOBAL BASIS THE PROBABILITY (IN PERCENT) TH
   1AT N OR MORE SATELLITES WILL BE SEEN')
920 CONTINUE
    END
```

ORBINI

```
      SUBROUTINE ORBINI(I)
      COMMON/ORBIS/P(37,25)/CON/C(18)
      P(I,2)=P(I,2)*C(1)
      P(I,3)=P(I,3)*C(1)
      P(I,4)=P(I,4)*C(1)
      P(I,5)=P(I,5)*C(1)
      P(I,9)=SIN(P(I,4))
      P(I,10)=COS(P(I,4))
      P(I,11)=SIN(P(I,3))
      P(I,12)=COS(P(I,3))
      P(I,21) = P(I,22)*C(6)
      SAA=22808.*C(6)
      P(I,23)=(SAA/P(I,21))**1.5
      P(I,6)=P(I,21)*(1.-P(I,1)*P(I,1))
      P(I,7)=SQRT(  C(12)/P(I,6))
      P(I,8)=C(12)/(P(I,6)*P(I,6))
      RETURN
      END
```

ORBIT

```
      SUBROUTINE  ORBIT(I,T,PER,R,VEL,AC)
      COMMON/ORBIS/OP(37,25)/CON/C(18)
      DIMENSION R(3),VEL(3),AC(3),TRANS(3,3),Q(3),QEL(3),QC(3),U(36),
     1   E(36),BIGT(36),LILT(36),V(36),CV(36),SV(36),PER(36)
      REAL LILT
      IF(T.GT.0.) GO TO 10
      V(I)=OP(I,5)
      SINE=(SQRT(1.-OP(I,1)**2)*SIN(OP(I,5)))/(1.+OP(I,1)*COS(OP(I,5)))
      RAD=(OP(I,22)*(1.-OP(I,1)**2))/(1.+OP(I,1)*COS(OP(I,5)))
      E(I)=ARSIN(SINE)
      IF(OP(I,1).NE.0.) GO TO 15
      IF(V(I).LT.(C(3)/2.)) E(I)=E(I)
      IF((V(I).GE.(C(3)/2.)).AND.
     1   (V(I).LE.(3.*C(3)/2.))) E(I)=C(3)-E(I)
      IF(V(I).GT.(3.*C(3)/2.)) E(I)=C(4)+E(I)
      GO TO 20
   15 CONTINUE
      IF(RAD.LT.OP(I,22).AND.V(I).LE.C(3)) E(I)=E(I)
      IF(RAD.GT.OP(I,22)) E(I)=C(3)-E(I)
      IF(RAD.LT.OP(I,22).AND.V(I).GT.C(3)) E(I)=C(4)+E(I)
   20 CONTINUE
      BIGT(I)=(PER(I)*(E(I)-OP(I,1)*SINE))/(24.*C(4))
      LILT(I)=BIGT(I)
      GO TO 25
   10 DEL=.1
      LILT(I)=BIGT(I)+T
      E(I)=0.
   35 E(I)=E(I)+DEL
      Y=LILT(I)-(PER(I)*(E(I)-OP(I,1)*SIN(E(I))))/(24.*C(4))
      IF(ABS(Y).LE..00001) GO TO 30
      IF(Y.GT.0.) GO TO 35
      E(I)=E(I)-DEL
      DEL=DEL/10.
      GO TO 35
   30 CONTINUE
      IF(E(I).GE.C(4)) E(I)=E(I)-C(4)
      SINV=(SQRT(1.-OP(I,1)**2)*SIN(E(I)))/(1.-OP(I,1)*COS(E(I)))
      V(I)=ARSIN(SINV)
      RP=OP(I,22)*(1.-OP(I,1)*COS(E(I)))
      P=OP(I,22)*(1.-OP(I,1)**2)
      IF(OP(I,1).NE.0.) GO TO 40
      IF(E(I).LT.(C(3)/2.)) V(I)=V(I)
      IF((E(I).GE.(C(3)/2.)).AND.
     1   (E(I).LE.(3.*C(3)/2.))) V(I)=C(3)-V(I)
      IF(E(I).GT.(3.*C(3)/2.)) V(I)=C(4)+V(I)
      GO TO 25
   40 CONTINUE
      IF(RP.LT.P.AND.E(I).LE.C(4)) V(I)=V(I)
      IF(RP.GT.P) V(I)=C(3)-V(I)
      IF(RP.LT.P.AND.E(I).GT.C(4)) V(I)=C(4)+V(I)
   25 CONTINUE
      CV(I)=COS(V(I))
      SV(I)=SIN(V(I))
      U(I)=V(I)+OP(I,2)
      OP(I,13)=COS(U(I))
      OP(I,14)=SIN(U(I))
      SPH=OP(I,14)*OP(I,9)
      CPH=SQRT(1.+SPH*SPH)
```

ORBIT

```
OP(I,15)=ARSIN(SPH)*C(2)
OP(I,18)=U(I)
F1=1.+OP(I,1)*CV(I)
Q(1)=OP(I,6)/F1
Q(2)=0.
Q(3)=0.
QEL(1)=OP(I,1)*OP(I,7)*SV(I)
QEL(2)=OP(I,7)*F1
QEL(3)=0.
QC(1)=-OP(I,8)*F1*F1
QC(2)=0.
QC(3)=0.
CALL TRMATX (TRANS,I)
CALL MATMUL (TRANS,Q,R)
CALL MATMUL (TRANS,QEL,VEL)
CALL MATMUL (TRANS,QC,AC)
OP(I,24)=(T- AINT(T+.5))*C(4)
OP(I,16)=ATAN2(R(2),R(1))-OP(I,24)
OP(I,16)=OP(I,16)*C(2)
RETURN
END
```

TRMATX

```
SUBROUTINE TRMATX(TR,I)
DIMENSION TR(3,3)
COMMON/ORBIS/OP(37,25)/CON/C(18)
TR(1,1)=OP(I,12)*OP(I,13)-OP(I,11)*OP(I,10)*OP(I,14)
TR(1,2)=OP(I,12)*OP(I,14)+OP(I,11)*OP(I,10)*OP(I,13)
TR(1,3)=OP(I,11)*OP(I,9)
TR(2,1)= OP(I,11)*OP(I,13)+OP(I,12)*OP(I,10)*OP(I,14)
TR(2,2)=-OP(I,11)*OP(I,14)+OP(I,12)*OP(I,10)*OP(I,13)
TR(2,3)=-OP(I,12)*OP(I,9)
TR(3,1)=OP(I,9)*OP(I,14)
TR(3,2)= OP(I,9)*OP(I,13)
TR(3,3)=OP(I,10)
TR(1,2)=-1.*TR(1,2)
RETURN
END
```

MATMUL

```
      SUBROUTINE MATMUL(T,V,O)
      DIMENSION T(3,3),V(3),O(3)
      DO 10 I=1,3
      O(I)=0.
      DO 10 J=1,3
   10 O(I)=O(I)+T(I,J)*V(J)
      RETURN
      END
```

POINT

```
SUBROUTINE POINT(ALO,ALA,TIM,VEC)
COMMON/CON/C(18)
DIMENSION VEC(3)
EW=ALO*C(1)+C(4)*TIM
SN=ALA*C(1)
VEC(1)=C(10)*COS(SN)*COS(EW)
VEC(2)=C(10)*COS(SN)*SIN(EW)
VEC(3)=C(10)*SIN(SN)
RETURN
END
```

TAAT

```
      SUBROUTINE TAAT (MAX,MXX,MATRIX)
      DIMENSION MATRIX(58905,4)
      DO 10 I=1, 58905
      DO 10 II=1,4
   10 MATRIX(I,II)=0
      IF(MAX.LT.3) GO TO 30
      MXX=(MAX-2)*(MAX-1)*MAX/6
      MMM=MAX-1
      MMN=MAX
      MMO=MAX+1
      NA=0
      DO 25 K=2,MMM
      KO=K+1
      DO 20 L=KO,MMN
      KT= L+1
      DO 15 M=KT,MMO
      NA=NA+1
      MATRIX(NA,2)=K
      MATRIX(NA,3)=L
      MATRIX(NA,4)=M
   15 CONTINUE
   20 CONTINUE
   25 CONTINUE
   30 RETURN
      END
```

VOLUME

```
      SUBROUTINE VOLUME (UVEC,IDSAT,VOL)
      DIMENSION UVEC(37,3),IDSAT(4),ONE(3),TWO(3),THREE(3),FOUR(3)
      DIMENSION TMF(3),TMT(3),OMT(3),CROSS(3)
      KA=IDSAT(1)
      KB=IDSAT(2)
      KC=IDSAT(3)
      KD=IDSAT(4)
      DO 10 N=1,3
      ONE(N)=UVEC(KA,N)
      TWO(N)=UVEC(KB,N)
      THREE(N)=UVEC(KC,N)
   10 FOUR(N)=UVEC(KD,N)
      CALL VECTOR (TWO,2,FOUR,TMF)
      CALL VECTOR (THREE,2,TWO,TMT)
      CALL VECTOR (ONE,2,TWO,OMT)
      CALL VECTOR (TMT,3,TMF,CROSS)
      VOL=ABS(DOT(OMT,CROSS))
      RETURN
      END
```

COVNAV

```
      SUBROUTINE COVNAV (G,ID,NAT,SIG)
      DIMENSION  ID(37),B(4),SIG(6),G(37,4),IPIVOT(4),INDES(4,2)
      REAL*8 TRA(4,4),BBB(1,1),DETERM,FPTMAX
      DATA FPTMAX/Z7FFFFFFFFFFFFFFF/
      DO 20 I=1,4
      DO 15 J=1,I
      TRA(I,J)=0.
      DO 10 K=1,NAT
      L=ID(K)
      TRA(I,J)=TRA(I,J)+G(L,I)*G(L,J)
   10 CONTINUE
      TRA(J,I)=TRA(I,J)
   15 CONTINUE
      TRA(I,I)=TRA(I,I)+1.E-12
   20 CONTINUE
      CALL DMATRI (TRA,4,4,BBB,1,0,IPIVOT,INDES,ISING,DETERM)
      IF(ISING.NE.0) STOP
      IF(DETERM.EQ.FPTMAX) GO TO 25
      SIG(1)=DSQRT(TRA(3,3))
      SIG(2)=DSQRT(TRA(1,1)+TRA(2,2))
      SIG(3)=DMAX1(DSQRT(TRA(1,1)),DSQRT(TRA(2,2)))
      SIG(4)=DSQRT(TRA(4,4))
      SIG(5)=DSQRT(TRA(1,1)+TRA(2,2)+TRA(3,3))
      SIG(6)=DSQRT(TRA(1,1)+TRA(2,2)+TRA(3,3)+TRA(4,4))
      RETURN
25    WRITE(6,30)
30    FORMAT(1H ,/,3X,'DETERMINATE REACHED MAXIMUM VALUE')
      STOP
      END
```

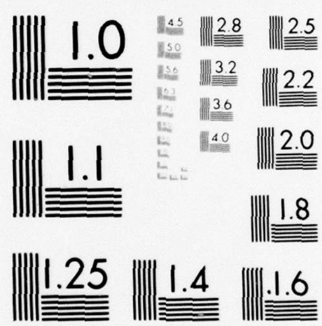
BLK DATA

```
 BLOCK DATA
 COMMON/CON/C(18)
 DATA C/.01745329252,57.295779513,3.1415926536,6.28318530718,
11.57079630,6076.116,0.,0.,0.,2.0926143504E+07,
27.29211585E-05,1.4076380E+16,365.2563835 ,92.91
3E+06,0.0167272,23.44436,-77.7303,5280./
 END
```

AD-A043 744 RAND CORP SANTA MONICA CALIFORNIA F/G 17/7
GEOMETRIC PERFORMANCE OF PSEUDORANGING NAVIGATION...ETC.(U)
JUL 77 LAMAR, JEANNINE V. ROWELL, L.N. F49620-77-C-0023
UNCLASSIFIED R-1949-AF N/L

2 OF 2
AD A
043744

END
DATE
FILMED
4-81
DTIC



MICROCOPY RESOLUTION TEST CHART

VECTOR

```
      SUBROUTINE VECTOR(V1,I,V2,V3)
      DIMENSION V1(3),V2(3),V3(3)
      GO TO (10,15,20), I
   10 V3(1)=V1(1)+V2(1)
      V3(2)=V1(2)+V2(2)
      V3(3)=V1(3)+V2(3)
      RETURN
   15 V3(1)=V1(1)-V2(1)
      V3(2)=V1(2)-V2(2)
      V3(3)=V1(3)-V2(3)
      RETURN
   20 V3(1)=V1(2)*V2(3)-V1(3)*V2(2)
      V3(2)=V1(3)*V2(1)-V1(1)*V2(3)
      V3(3)=V1(1)*V2(2)-V1(2)*V2(1)
      RETURN
      END
```

DOT

```
FUNCTION DOT(V1,V2)
DIMENSIONV1(3),V2(3)
DOT=V1(1)*V2(1)+V1(2)*V2(2)+V1(3)*V2(3)
RETURN
END
```

UNIVEC

```
SUBROUTINE  UNIVEC (V,UV)
DIMENSION  V(3),UV(3)
DENOM = SQRT(DOT(V,V))
UV(1) = V(1)/DENOM
UV(2) = V(2)/DENOM
UV(3) = V(3)/DENOM
RETURN
END
```

TALL

```
      SUBROUTINE TALL (MAX,MXX,MATRIX)
      DIMENSION MATRIX(58905,4)
      DO 10 I=1,58905
      DO 10 II=1,4
   10 MATRIX(I,II)=0
      IF(MAX.LT.3) GO TO 35
      MXX=(MAX-3)*(MAX-2)*(MAX-1)*MAX/24
      KK=MAX-3
      LL=MAX-2
      MM=MAX-1
      NN=MAX
      NA=0
      DO 30 K=1,KK
      KO=K+1
      DO 25 L=KO,LL
      KT=L+1
      DO 20 M=KT,MM
      KP=M+1
      DO 15 N=KP,NN
      NA=NA+1
      MATRIX(NA,1)=K
      MATRIX(NA,2)=L
      MATRIX(NA,3)=M
      MATRIX(NA,4)=N
   15 CONTINUE
   20 CONTINUE
   25 CONTINUE
   30 CONTINUE
   35 RETURN
      END
```

REFERENCES

1. Bogen, A. H., *Geometric Performance of the Global Positioning System,* The Aerospace Corporation for Space and Missile Systems Organization, AFSC, SAMSO-TR-74-169, 21 June 1974.

2. Unpublished analysis by J. J. Mate, The Rand Corporation, September 1976.